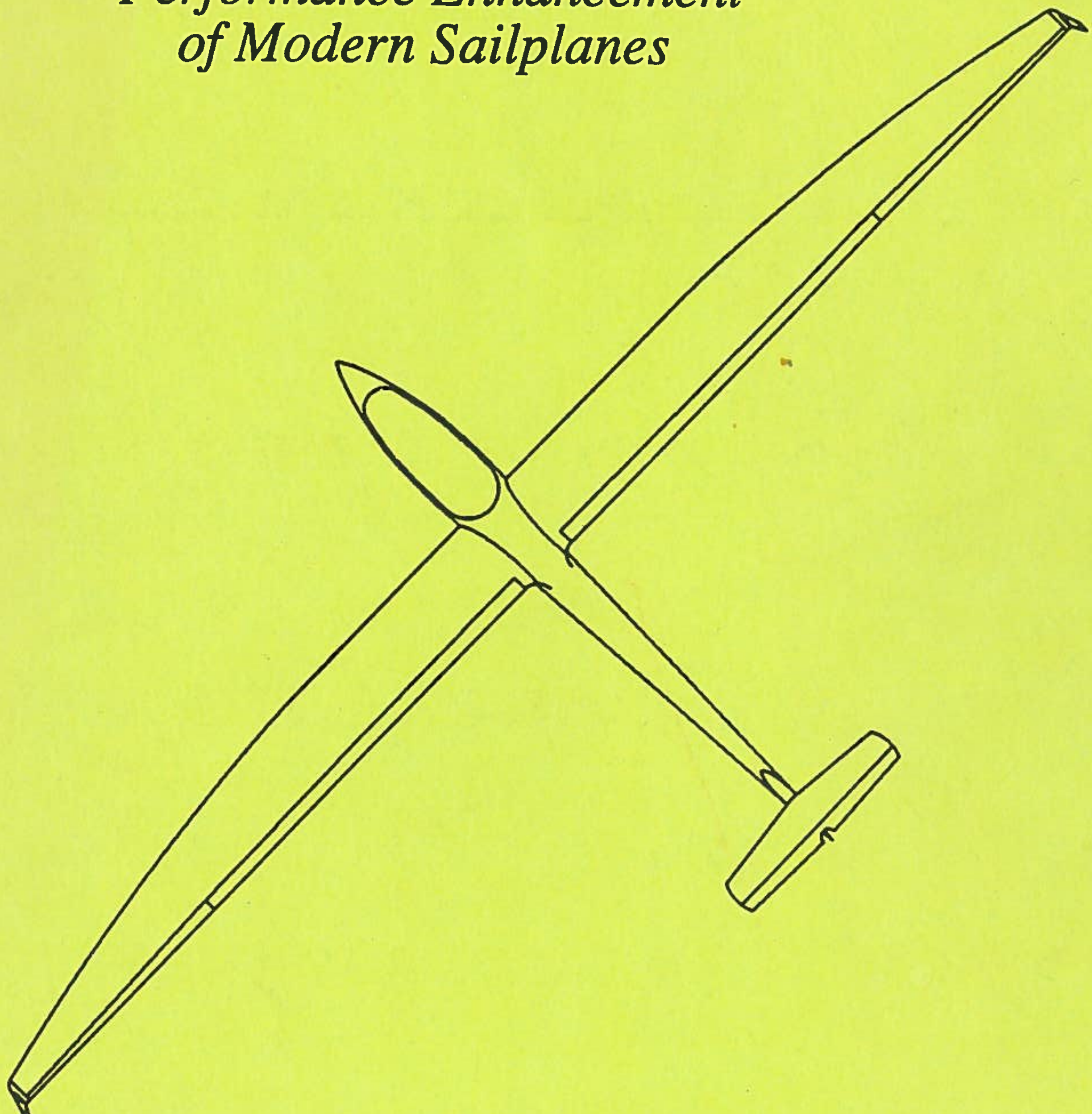
Performance Enhancement of Modern Sailplanes



by Peter C. Masak

*This booklet is
dedicated to the success
of Scimitar, and all that
we expect her to
achieve.*

*Peter Masak
Houston, Texas 11/91*

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Chapter 1

INTRODUCTION

Despite the wealth of information available on the *science* of aerodynamics, only bits and pieces of knowledge are available related to the *art*. This booklet is an attempt to help unravel some of the mysteries of the performance enhancement techniques that some of the more successful competition soaring pilots have used to help them win. Whether you are a zen-driven all-out racing pilot or just a weekend 2-33 jockey, the understanding of the physics and the knowledge of how to relate this to practical use can be most interesting and fruitful.

Some of the best documented work on the subject can be traced to two legends in American Soaring history - Dick Johnson and Wil Schuemann - who very successfully cleaned up off-the-shelf sailplanes with spectacular results. Other noteworthy contributors include George Moffat and Richard Schreder. Much of the information which follows has originated with these gentlemen. Johnson, Moffat and Schreder each won many national championships and represented the United States in world competition. No doubt some of their success was attributable to having the best performing sailplane of the day.

Following is a short list of the topics to be discussed in this paper.

1. Quick and Dirty Performance Gainers
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1.1 PHILOSOPHY ON MODIFICATIONS

It should be emphasized right from the start that if you are *not* going to be conscientious about keeping your sailplane airworthy and working professionally, you have *NO* business even starting. If your idea of sailplane tune-up amounts to taping things with aluminum duct tape and using automobile parts, then you might as well take out a big life insurance policy because at some point you are going to kill yourself.

Be careful that whatever you do to your airplane is aerodynamically and structurally OK - if you're not sure of your competence to judge the integrity of the modification that you've made, have someone more qualified offer an opinion as to the possible consequences of what you're doing.

If you are working with a certified aircraft, then the rules on modifications are much stricter than for experimental aircraft. For a certified aircraft, you are required to make a log book entry and to complete FAA form 337. This will have to be signed by an FAA certified aircraft mechanic *before* the glider and modifications are considered airworthy.

Chapter 2

QUICK AND DIRTY PERFORMANCE GAINERS

Several items could be considered as *quick and dirty*, since they can result in noticeable improvement in performance without involving a great deal of effort. These will be elaborated on in detail in the following paragraphs.

2.1 SEALING

Sealing any sailplane so that you minimize leaks from the inside to outside is the most basic step to performance enhancement. Taking little strips of weather-stripping and gluing them to canopy rails, wing roots, and control contact points is very helpful. For ideas on what to do, consult with a friend that has the same aircraft.

The ASW-20, for example, has control rod seals built into the wing, so you don't need anything there. However, the back of the canopy right above the pilot's head isn't sealed at all - it howls at high speed and in cold weather. The tongue and groove fitting arrangement that seals the rest of the canopy doesn't extend to the area at the rear of the canopy, so here's where a little foam seal is most crutial. Also, the landing gear compartment is unsealed, which means that lots of air leaks out of the cockpit and through the gear doors. This surely can't be doing any good to the boundary layer. Again, the solution is to use foam tapes or clear bathtub caulking around the seat pan area where air might leak.

Dick Johnson offers some helpful suggestions on how to maintain control seals on Ventus and Nimbus sailplanes. Figure 2-1 shows a side view of a section through the aileron or flap on the wing, and shows the preferred method for sealing the lower portion of the control surface.

On symmetrical control surfaces such as rudders and elevators, either a foam weather-strip or dacron fabric rolling seal can be applied. The foam weather strip is easier to apply but ultimately may be less durable than the dacron system (figure 2-2).

2.2 WING ROOT SEALS

Most sailplanes don't have any provision for wing root control rod seals, so this is an area that you are likely going to have to tackle. If you don't seal off the wing root, air is going to flow from the fuselage, out into the wing, and then spill out over the flaps. Standard class machines don't have this problem, but if you have a flapped sailplane this is an area worth looking into.

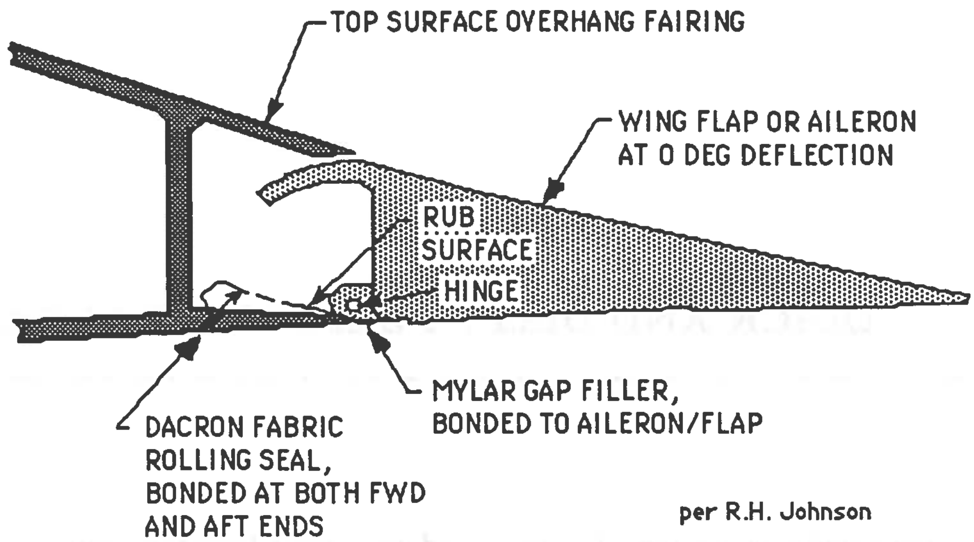


Figure 2-1. Mylar/Dacron Rolling Control Seal -Ventus

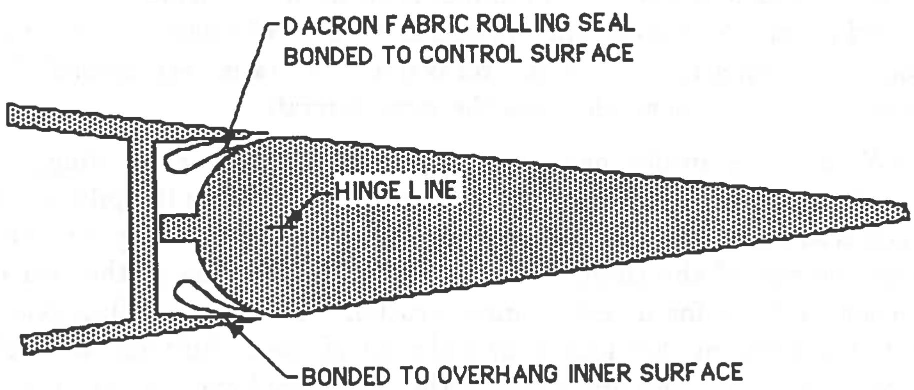


Figure 2-2. Elevator/Rudder Control Seal

One option is to buy some vinyl shower curtain material and make up some seals. All you have to do is to cut, shape, and bond (with contact cement) the vinyl shower curtain into the form of a funnel. Then you bond one end to the wing and use nylon tie wraps to secure the other end to the control rod (see figure 2-3). The same arrangement may be used for the elevator pushrod. A better material than vinyl would be an elastomer coated fabric.

A more professional approach is to purchase rubber bellows of the appropriate size and to bond them onto your wing root. These rubber rod covers normally are used for protection of hydraulic and pneumatic cylinder rods.

The climb performance of the Ventus sailplane suffers markedly from not having a good wing root seal. The factory provides a rubber bellows type seal on the flap torque tube, inside the fuselage. After several years, the rubber degrades and cracks, allowing air from

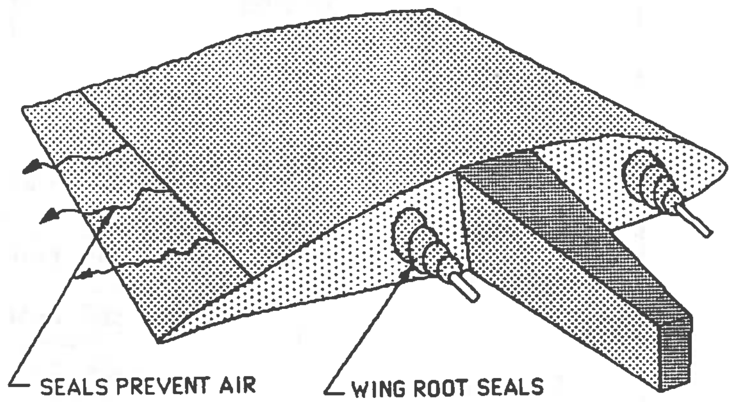


Figure 2-3. Wing Root Seals

the fuselage to spill out into the sensitive area at the wing root. If you own one of these sailplanes, you should periodically check this boot and see if it has become debonded or ruptured.

2.3 SANDING AND FILLING

All sailplanes undergo a post-curing process that results in waviness and deformation being introduced into the wingskins. On the new model sailplanes that use thick sandwich skins, this is less of a problem than it used to be. The complete curing process may take an entire season or longer from the time of manufacture, so virtually new sailplanes may require touch-up sanding.

Waviness most commonly occurs around spar caps, spoiler boxes, and other areas where there is a variation in resin concentration in the glass. Anything greater than a two-thousanths of an inch waviness is considered to be detrimental. Fortunately, you can feel this with your hand - if you run your hand fore-aft in the direction of the airflow, then you will be able to notice the bump. The remedy is to take 220 grit sandpaper and to sand out the anomaly, taking care not to sand so far as to alter the profile. When you sand, you should use hand motions that work at a 45 degree angle referenced to the leading edge, and alternate your sanding pattern so as to maintain the best uniformity. After taking out the high points, finish sanding with 400, then 600/1200 grit sandpaper until all the scratches are gone. Figure 2-4 shows some waviness data measured on the wing of an LS-1C, which had a lot of sanding done on it prior to a world contest. Despite all the effort involved, there were still waves on the order of 4 thousanths of an inch in parts of the wing. This could cause premature boundary layer transition.

Great care must be exercised when dealing with the areas of high curvature at the leading edge. It's very easy here to introduce additional waviness, or to alter the wing profile without even batting an eye. Since the airfoil curvature changes so fast near the leading edge, it's easy to oversand, with the likely result that the nose is too rounded and the airfoil too flat. (figure 2-5).

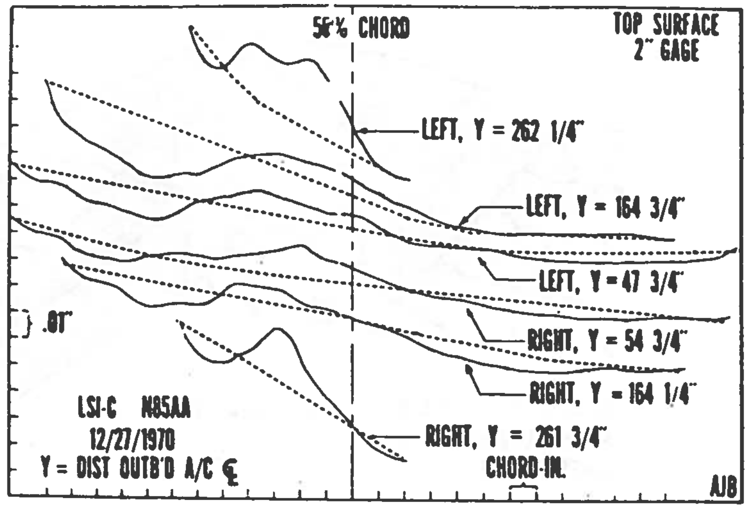


Figure 2-4. Waviness Data from an LS-1c

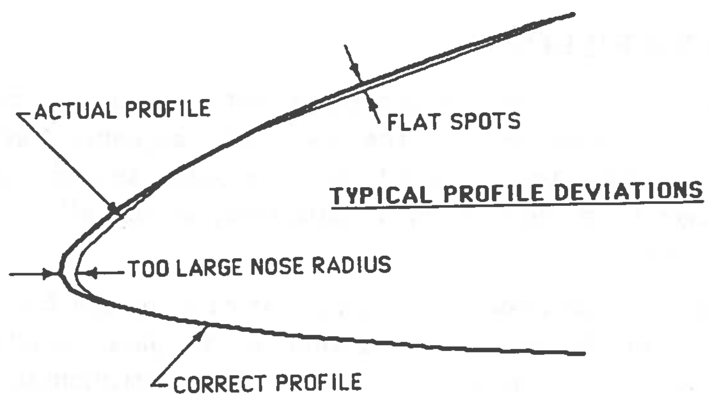


Figure 2-5. Distortions Introduced by Sanding

If you had profile templates to check the accuracy of factory new sailplanes, you would probably be shocked to discover how far the profiles typically deviate from the optimum. It's easy to see why, when you consider how a wing is manufactured.

The wing is molded in two pieces and joined with glue at the leading and trailing edge. To get a decent glue joint there's a little bit of overlap at the nose. This joint then needs to be sanded smooth to make it pretty and aerodynamic. Since there's a significant buildup of material there, it's easy to get carried away and inadvertenly blunt the leading edge by oversanding.

Incidentally, most ships that come new out of the factory are also guilty of this. I bet that in the sailplane factories that the 'entry-level' position includes time in the wing sanding group. Practically all new gliders that come from the factory have leading edges that are too round - at least when compared with what they should be. I made some crude

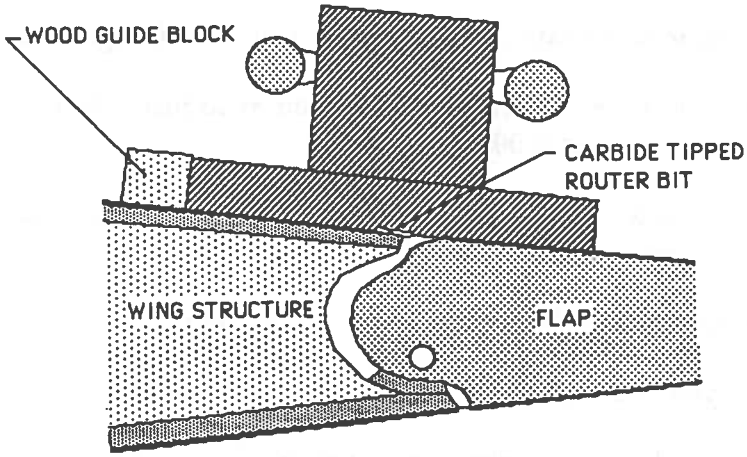


Figure 2-6. Routing the Wing for Accepting Mylar Seals

templates for my ASW-20 and checked several other competitors ships - most of them were off profile as much as 3/32 of an inch. Not surprisingly the gentleman that had the truest wing seemed to have the best climb performance.

2.4 MYLAR SEALS

Mylar seals are easily the most cost effective way of improving the performance of your sailplane. These are a simpler and more effective way to obtain a smooth transition from wing to control surface than the fabric/rolling seal discussed previously. The performance is improved up to two L/D points by the addition of these seals to moving control surfaces. They prevent crossflow from the high pressure side of the wing or control surface from bleeding over to the low pressure side.

When airfoils are tested in the tunnel, they always have their control gaps smoothed and taped. However, this hardly represents the real life world, where you need a reasonable gap to avoid jamming your controls in flight. The original factory ships, until recently, were supplied with a wide and rough textured adhesive tape which was applied to the bottom surface of the flaps and ailerons. Due to the nature of the tape and the wide gap, a big bump appears at this joint. If you push the bump into the joint, this leaves about a $\frac{1}{4}$ x $\frac{1}{4}$ square depression, which can't possibly be doing any good to the airflow.

Putting on new sliding contact mylar seals smooths the joint beautifully on top and bottom, while still allowing full control movement. Applying the mylar seals however takes some effort if you are really going to do it right. The mylar material is 0.007 inches thick - this doesn't seem like much, yet aerodynamically it will disturb the flow if the front lip of the mylar protrudes above the surface.

To get a perfect seal, you should consider either routing or shaving a groove in your gel coat equal in depth to the depth of the adhesive plus mylar (about 0.012 inches). You should allow yourself a full weekend of time to get the job done. Here's a list of steps if you decide to use a router. (see figure 2-6):

1. Set up the wing on boxhorses

2. Measure the appropriate distance to set guide blocks for your router
3. Using double sided tape, secure 2 in. x 1 in. wooden guide blocks
4. Set the micrometer adjustment on the router to just take off the gelcoat but not cut into the glass (about 0.005-0.010 in.)
5. Cut a groove for the mylar seals using a carbide tipped router bit. Use water as coolant to avoid overheating the fiberglass
6. Seal the exposed surface with thinned epoxy (Epikote)
7. Install mylar seals using pressure-sensitive acrylic tape
8. Using a wood block, apply heavy pressure to squeeze out air bubbles and activate the adhesive

Using power equipment like a router is a worrysome endeavor - if you slip and gouge the wing skin it will have to be repaired. On the other hand another alternative is to use a very sharp chisel and shave off the gel coat. Fred Schmidt did this on his ASW-20 and achieved excellent results. He found a long steel straightedge, attached it to his wing using double sided adhesive tape, and used it as a guide to direct the chisel. By holding the chisel at a very shallow angle to the surface, you can shave off the gel coat. When there is only about 5 ten-thousanths of gel coat remaining, the wing skin will be faintly visible through the gel coat. You should not try to go deeper than this.

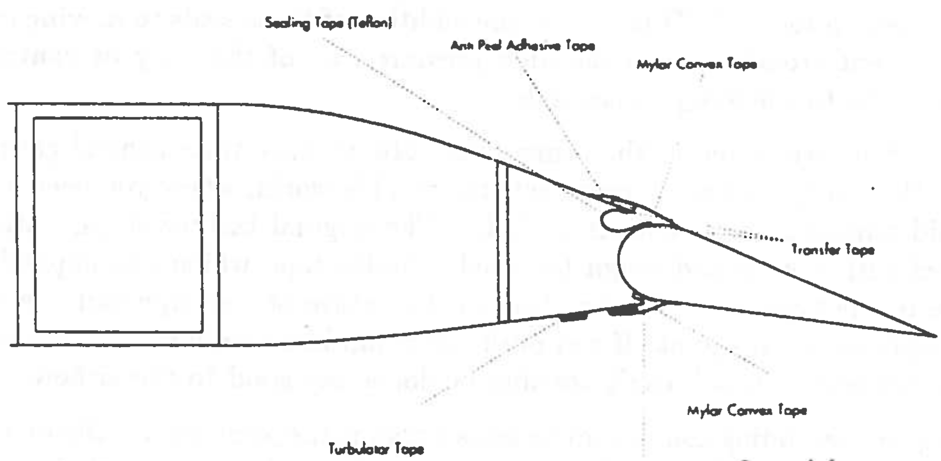


Figure 2-7. Mylar Control Seals in Place

Mylar seals are now commonly available from a variety of soaring parts suppliers in the United States. Standard widths include 22mm, 25mm, 30mm, and 37mm. These same seals would probably work well on any other glass sailplane. If you'd rather make your own however, you can, by purchasing 7 or 10 mil mylar drafting film, and form a permanent radius in it by putting the piece in a 3-1/2 inch diameter metal tube, which in turn is heated to the plastic temperature of the material (about 350 degrees). After forming the radius in

the mylar, you cut it on a large sheet-metal shear and apply 1/2 inch double sided tape to the mylar. The TESA company of West Germany sells an advanced acrylic double sided tape which provides excellent adhesion when bonding mylar to fiberglass. The adhesive has a temperature rating in excess of 200 deg F and a remarkably high peel strength of 72 oz/in. This exceeds the bond strength available from contact cement for example. This pressure sensitive tape is the same material now used by the glider factories in Europe.

Mylar seals also work very well on the horizontal stabilizer. In fact, if you put them on the lower surface of the ASW-20 elevator joint you'll get a significant reduction in noise. If you've ever stood by the finish gate as some ASW-20's come flying by you'll have noticed a very loud howling sound like someone was blowing air across the neck of an open beer bottle. Well, all this noise comes from the elevator joint on the ASW-20, and all that energy being converted into sound couldn't be helping the performance too much.

2.5 TURBULATORS

Many sailplanes using laminar airfoils are known to benefit from the application of turbulators to the lower wing surface. Wind tunnel and flight tests on a variety of sailplanes confirm that they reduce the drag coefficient of the wing and tail. Sailplanes that are known to respond positively to turbulators include the ASW-20, ASW-24, the Nimbus III, Cirrus, and DG-600.

The theory behind their use is simple, and perhaps is best explained by reference to a golf ball. The dimples on a golf ball are there to stir up the airflow in the sluggish boundary layer enough so as to delay (but not eliminate) separation. The additional skin friction drag of the dimples is more than offset by the reduced drag of the smaller separation drag, so the golf ball travels considerably farther before touchdown. (figure 2-8).

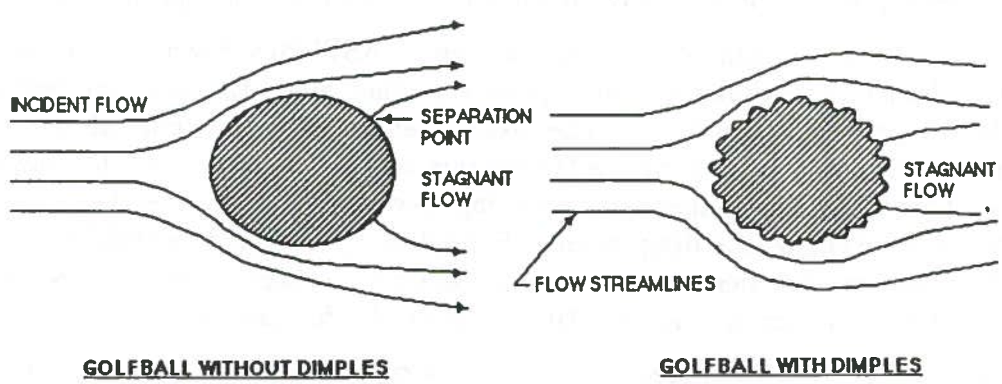


Figure 2-8. Separation Drag Effects on Golfballs

A modern laminar flow sailplane airfoil also has separation bubbles that disturb the flow profile and increase drag, particularly at low speeds (low Reynold's numbers). At approximately 60-90% of the airfoil's chord, the airflow separates from the wing briefly, and then reattaches in turbulent flow. The distortion of the flow profile caused by the separation

increases the effective thickness of the wing as seen by the air and therefore increases the drag.

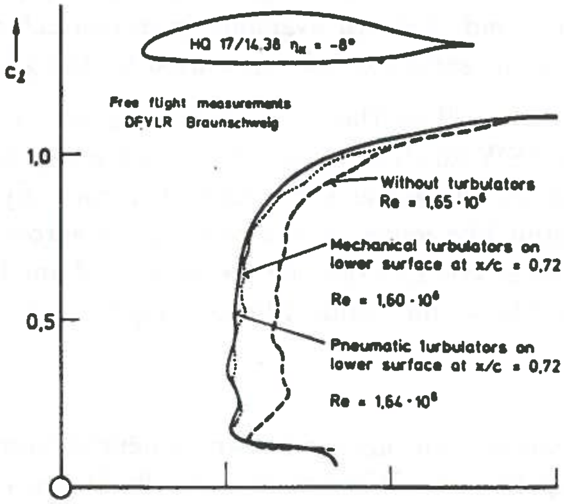


Figure 2-9. The effects of turbulators on Boundary Layer Flow

By introducing little vortex generators or turbulators just in front of the separation bubble, we can eliminate it altogether and just have laminar flow transitioning directly to turbulent flow (figure 2-9). The added drag of the turbulator strip is less than the drag due to the separation bubble itself. Turbulator strips are normally only applied to the bottom of the wing (The new DG-600 sports turbulators on both top *and* bottom surfaces). The magic point varies from one sailplane to another, however for the ASW-20 it's 72 % of chord. For the Standard Cirrus, it's 67 %. On the ASW-20 (I use stock Schempp-Hirth supply), the turbulators are only put on the inboard wing section. According to Mike Maxwell, who did extensive flight testing on the ASW-20, turbulators extending outboard beyond the flap-aileron junction of the ASW-20 will cause a peculiar high speed buffet.

Mike did extensive flight comparison testing of ASW-20's flown side by side in still air, with and without turbulators. He reports that they aided the sailplane performance both at the low and high speed end. The greatest effect however occurs at the low speed end - for the ASW-24, bottom surface turbulators reduce the airfoil profile drag coefficient by 27 %. This number is somewhat misleading however. A more objective comparison would be to compare the profile drag on an airfoil optimally designed to avoid laminar separation bubbles, and another designed to take maximum advantage of turbulators. In this case the gain with turbulators is much less (in the order of a few percent).

For other sailplanes, you'll need to do a lot of experimentation to get a good result if someone else hasn't already. You'll need to determine the laminar separation point (which varies with airspeed) which is most easily done using a procedure that involves a stethescope and a capilliary tube taped to the wing. The procedure is well documented by Wil Schuemann in his paper. Another technique is to use a trailing edge mounted drag rake and to install various turbulators in front of the rake. A series of calibration flights with no turbulators followed by a number of calibration flights with turbulators at a variety of likely positions in front of the rake will be definitive.

Sailplane	Optimum Turbulator Location	Airfoil
Grob 103	65 %	E-603
Speed Astir	68 %	E-662
Std. Cirrus	67 %	
LS-4	67 %	
Mosquito	not recommended	
ASW-20	72 % (inboard wing only)	FX-62-K-131
ASW-24	76 %	DU-84-158
Discus	72 % (root) 69 % (tip)	
Ventus/Nimbus III	75 %	FX-79-K-144

Table 2-1. Known Optimal Locations of Turbulators

Another procedure is to run a computer boundary layer analysis on the airfoil so as to determine the location on the airfoil where the flow starts to decelerate. This is evident in figure 2-10 which shows a decelerating flow on the FX-79-K-144 airfoil at 75 %. This coincides precisely with the optimal point determined experimentally by Richard Johnson.

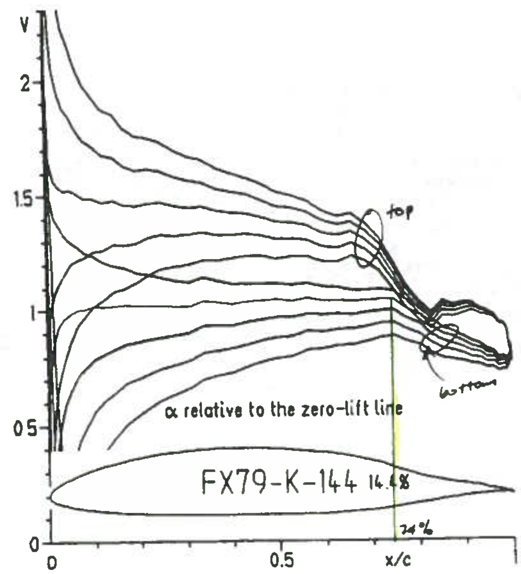


Figure 2-10. Boundary Layer Analysis for FX-79-K-144 Airfoil

The use of turbulators is not necessarily restricted to only the airfoil of course, since they aught to work well at any point on the sailplane where separation bubbles are likely to exist. The new ASW-24, for example, has turbulators everywhere except the top side of the wing. Both sides of the vertical and horizontal stabilizer and the entire lower surface of the wing are covered with zig-zag style turbulator tape.

Recent wind tunnel tests performed by Dieter Althaus at Stuttgart University have confirmed the performance benefits of turbulators used on tailplanes. Almost all of the modern sailplanes built in the last 20 years use the 'classic' symmetrical Wortmann FX 71-L-150/30 airfoil. At zero control deflection, there is no performance gain with turbulators. However with 15 degrees control deflection, a laminar separation bubble forms rearward from the control hinge. With a turbulator however, the bubble is eliminated and the drag may be as much as 50 % lower (see figure 2-11), at a Reynolds number of 0.7 million.

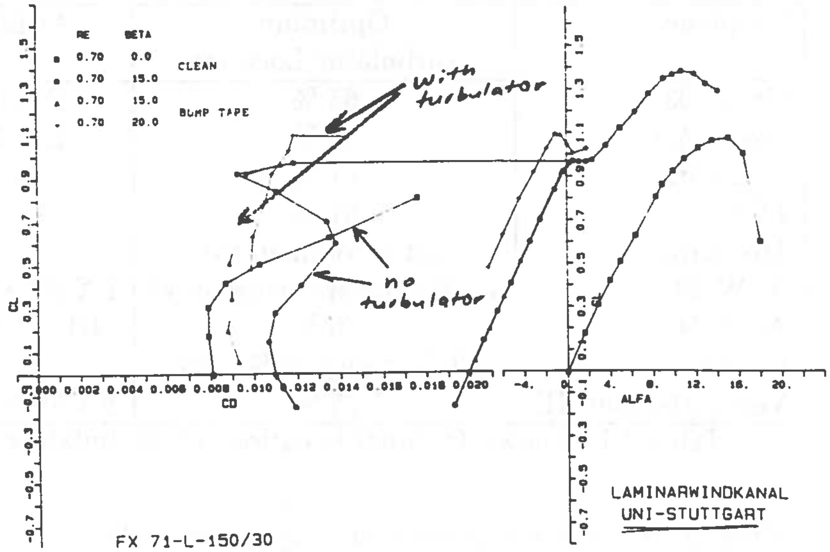


Figure 2-11. Cl vs Cd comparison for tailplane profiles w/wo turbulators

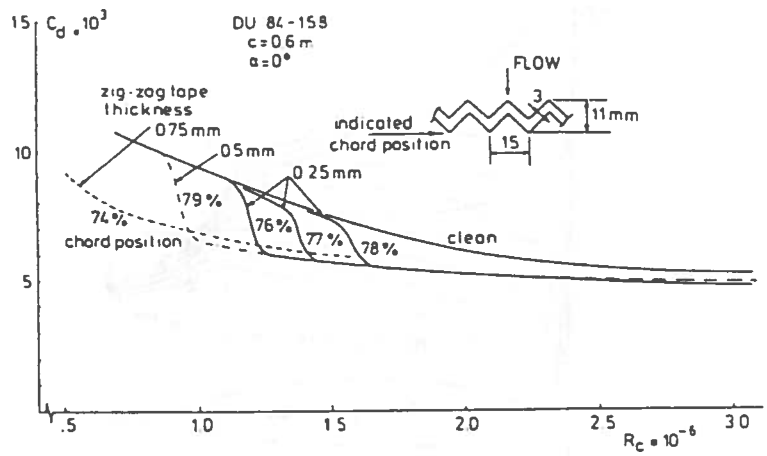


Figure 2-12. Thickness Effects of Turbulators

2.6 TURBULATOR SHAPE

Tests on the ASW-24 indicated that the optimal turbulators were zig-zag shaped, with a 15mm pitch, an 3 mm width, and an 11mm depth. The thickness of the turbulators proved to be important (figure 2-12). The thickest turbulators (0.75mm) had slightly higher high-speed drag, but offered a significant advantage at low circling speeds. The thinner turbulators did not trip the flow at all for example (0.25 mm for example), at low speeds.

Schempp-Hirth dealers sell dimpled tape, which includes a self adhesive backing. I have had very poor luck with the material, and find that it is very difficult to keep the turbulator tape on the wing, although it appears to work well as long as it stays on the wing.

2.7 BLOWHOLES

Several production sailplanes such as the DG-300, ASW-20B and ASW-22 use blowholes in place of mechanical turbulators. The advantages of blowholes are that they will still turbulate the boundary layer even if they are located behind the point of laminar separation (in contrast to mechanical turbulators). Blowholes are small diameter holes drilled into the bottom wing surface, which connect to an inner wing duct fed by a ram air pitot source. Air bleeds out of these small diameter holes (they are lined with stainless steel hypodermic tubes). Compared to turbulators, this is a very expensive way to control the boundary layer.

If you've got blowholes, you would be well advised to make sure that all the little holes are open, and not clogged with wax or dirt. You need to get a miniature set of round files (available for only a few dollars from welding supply stores for cleaning out the tips of acetylene torches) and clean out all the holes. The performance of a wing that has been designed to use turbulators or blowholes in the first place is *much worse* when the turbulator tape is missing or the blow holes clogged, than a wing which wasn't intended to have them. Dick Johnson in the course of flight testing a new DG-300 found that many of the blowholes on the bottom surface of the DG were plugged ! After cleaning them out and retesting, he found a significant performance gain.

2.8 TAIL SKIDS

Here's an area where you're going to have to make a judgement decision. There's a small performance improvement available from replacing your tailwheel with a tailskid. A fixed tailwheel adds considerable directional stability, making it less likely that you might ground loop on takeoff or landing if you catch a wingtip. On the other hand, it's got inherently higher drag; so you make the call - performance in favor of safety and convenience ? Personally, I would put on the faired tailskid for contest flying and replace it with the more conventional tailwheel during the regular season (see figure 2-13).

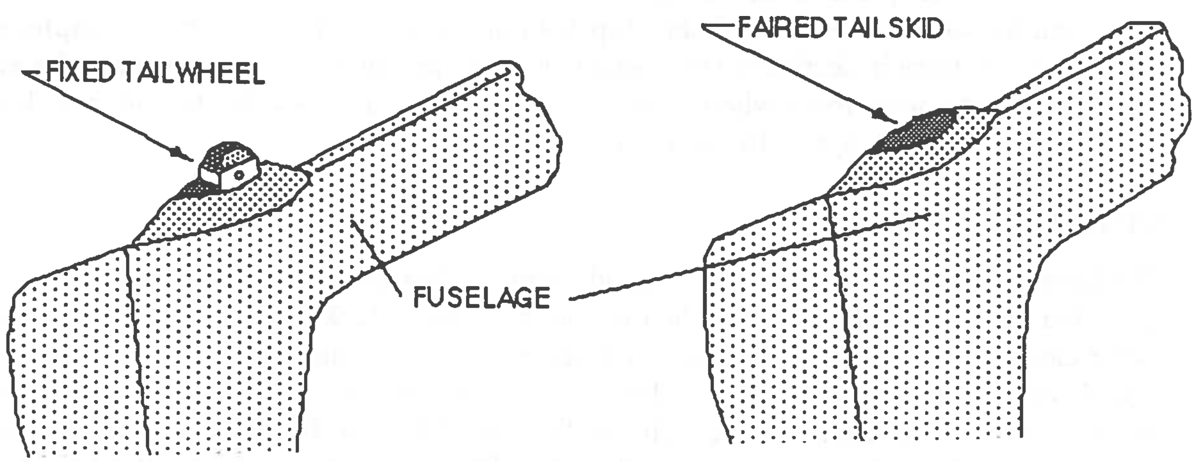


Figure 2-13. Fixed Tail-Wheel vs. Tailskid

2.9 BETTER COCKPIT EXHAUST

Wil Schuemann did some clever work on the Libelle, where he managed to improve the performance of the sailplane and the comfort level of the pilot at the same time. He designed a low drag air scoop that was incorporated as part of the gear doors, as well as a clever exhaust system that used a split fairing and open ports tucked in behind the tail skid (figure 2-14).

Figure 2-14. Tail Exhaust

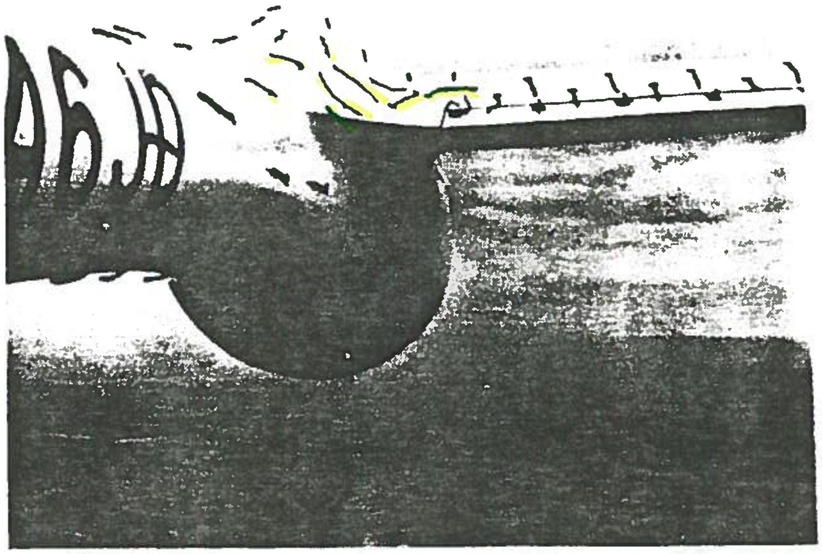
The principle is that, if you can bring air smoothly into the cockpit and then exhaust it back into the airstream without distorting the boundary layer anywhere, then you'll gain some performance. Obviously, you can't have an airtight ship (the pilot would quickly overheat), and so it's better to control the ventilation flow rather than have it spill out somewhere where it really disturbs something.

Alan Bikle recently has been selling a mod kit for the Ventus sailplane which enlarges the exhaust port at the back of the ship behind the skid. This reportedly improves the performance, since it decreases the cockpit internal pressure and reduces air leaks around the canopy and wing roots where they can really hurt. The few Ventus owners that I've talked to are quite happy with the mod.

2.10 VORTEX GENERATORS

We have long known that the key to good climb performance is a well faired fuselage-wing junction. The deceleration of flow behind the maximum thickness point of the fuselage and wing can result in separation, if the fuselage necks in too rapidly at the wing root. Some 1970's designs like the PIK-20 had bottleneck fuselages which tapered down too rapidly to maintain attached flow at high lift coefficients. This can be seen by reference to Dick Johnson's photographs on the wing root of the PIK (figure 2-15), taken at 39 knots. The separated flow is quite apparent and indicated by the reversed tufts at the wing root fillet.

More recent sailplanes like the LS-4,LS-6 and Pegasus have used more gentle tapers on the fuselage, in the wing root area. The Pegasus is essentially a copy of an ASW-20 fuselage; however it has been slightly refined and improved. One of the notable areas is at the wing



0° flap, 39 kt

Figure 2-15. Flow at the PIK-20 Root

root fillet.

Rick Wagner has tuft tested the '20 and found it to suffer from flow separation at the root at circling speeds. One simple solution might be to install small vortex generators just in front of the separation point, as determined by tuft testing.

Performance increases at low speed were demonstrated by German university students on the Stuttgart FS-31, and the Glasflugel Hornet. They placed three vortex generators in the wing root fillet on the top surface at approximately 40-50 % of chord. Flight test polars indicate a 1 point increase in L/D at approximately 50 kts.

The construction of the vortex generator is not documented, however from the Aerokurier article it appears to show an aluminum plate approximately 1.5 inches across, with two ends bent up vertically such that they project into the airflow about 3/8 inch. The two sides are not parallel, but rather appear to be inclined about 20 degrees to the relative airflow (figure 2-16).

You could probably build a set of vortex generators in a couple of hours and install them in a short time using contact cement. Should they work you will have gained some performance for relatively little investment in time. In comparison, the remainder of the modifications discussed herein are relatively major efforts.

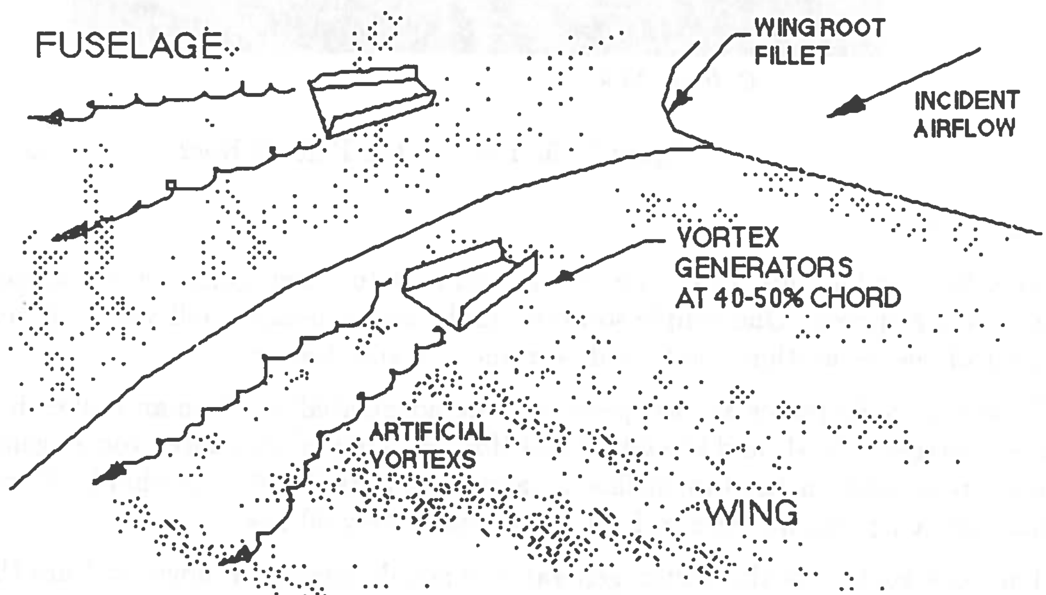


Figure 2-16. Vortex Generator

Chapter 3

LABOUR INTENSIVE MODIFICATIONS

3.1 WING PROFILING

This is an area where many of us fear to tread, but where good performance gains are available if you are willing to do it right and put up with hours of toil and agony. Dick Johnson is really the master at this game - he stated that profiling the wing on his PIK-20 was more productive than watching television. Dick demonstrated rather spectacular results on his PIK, wherein he was able to increase the performance of the ship from about 39:1 (factory condition) to somewhere in excess of 42:1 after a full winter of sanding and filling. Jim Cox from Dallas also claims to have gotten some good performance gains out of his LS-3, as did Dick Butler in his work on the Glasflugel 604. A.J. Smith improved the max L/D of Lawrence Wood's '604 by 6% as a result of reprofiling the leading edge of the ship, according to Dick Johnson's flight test results.

I've also heard some horror stories that might cause you to take a second look at this before starting. Someone out west apparently redid a PIK-20 wing and added something like 40 lbs of filler to the wing - only to find out that there was no performance gain ! Let me explain how you can avoid doing this to yourself (figure 3-1).

Figure 3-1. Problems with Overly Thick Sections

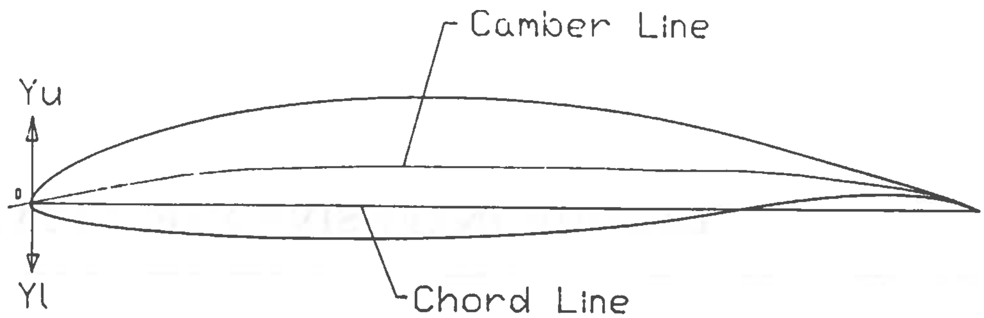


Figure 3-2. Airfoil Terminology

If you are going to profile your wing, the first thing that you should do is to take caliper measurements of the wing to determine the actual thickness/chord ratio. You'll need a giant set of calipers that can extend out from the leading edge over to the maximum thickness point. Then you take the thickness measurement and divide by the chord at that point to get the thickness/chord ratio. You'll then need to recalculate the wing profile coordinates to make them suitable for that particular thickness/chord ratio. This is easily done with a hand calculator. Let's say for example that your sailplane uses an FX-62-K-131 airfoil like the ASW-20A, and your wing thickness is 14.0% instead of the 14.4 % that it should be. Since the airfoil coordinates for that airfoil are only quoted for a 13.1 % thickness (that's what the 131 designation in the airfoil designation means), you'll have to alter the coordinates appropriately. *Don't* multiply the coordinates by the ratio of 14.0 to 13.1 - this is *NOT* correct !

Here are the steps to recalculate the coordinates (see figure 3-2)::

1. Wing coordinates are quoted in a table of X and Y values for the top and bottom surface, divided by the chord, ie X,Y_u ,Y_l.

2. Determine the mean camber point by calculating the halfway point between Y_u and Y_l for each X value. (figure 15)

3. Determine the distance between the mean camber point and the upper and lower coordinates, ie. $l_u = Y_u - \frac{Y_u+Y_l}{2}$, and $l_l = \frac{Y_u+Y_l}{2} - Y_l$.

4. Multiply this distance by the ratio of:

$$\alpha = \frac{desired\, airfoil\, thickness}{actual\, airfoil\, thickness}$$

   For this example the value would be $\alpha = \frac{14.0}{13.1}$.

5. Add this distance to the mean camber point at each X coordinate for both the top and bottom Y coordinate.

$$Y_u = Y_u + \alpha \times \left(Y_u - \frac{Y_u + Y_l}{2}\right)$$

This will give you a new airfoil with the thickness correctly adjusted for your sailplane. The performance of this airfoil should very closely match the predicted values for the nominal airfoil, since you have maintained the same camber line and shape factors. This can save you an *enormous* amount of filling work.

Getting the airfoil coordinates for your new ship could really be a trick, if it's a new sailplane. One of the best sources of data is a book called the Stuttgarter Profilkatalog, available from the University of Stuttgart in West Germany. This has the coordinates and data on most of the sailplanes that used Wortmann airfoils prior to 1980 (PIK, Mini-Nimbus, Nimbus II, LS-3,etc). Most of the newer ships like the Ventus, Nimbus III, LS-6, etc. use proprietary airfoils, however Dick Johnson recently published the airfoil coordinates for the Ventus/Nimbus III in *Soaring*. The Ventus/Nimbus III coordinates are reproduced here in chapter 5. In addition, the coordinates for the ASW-20A inboard section (modified FX-62-K-131) airfoil are also listed. The tip profile used on the '20 is an FX-60-126, tapering linearly from a 14.4% 62-K-131 at the aileron/ flap junction to an imaginary point at 16.6 meters where it is a 12.6% 60-126.

These airfoil coordinates were provided by Dan Somers, and also printed in the chapter 5. He took the original coordinates and modified them with his computer to improve the pressure distribution at the leading edge. The original Wortmann coordinates were a little rough in that area. Remember that they were developed in 1962, on old and slow computers ! I have built a sample wing section using these coordinates and tested the profile in a wind tunnel. The measured drag coefficient at 0 deg angle of attack was 0.0048 (very good performance!).

More recently, Bill Hinote in California went through an extensive profiling campaign on his ASW-20A, using these profile coordinates as a basis. He reports excellent results on the basis of flight comparisons with other ships after modifications.

In this modern technology age, the toil of graphing out coordinates on a sheet of paper, pasting it to a sheet of aluminum, and cutting and filing is now obselete. Most people probably have access or know someone that has a Computer Aided Design (CAD) system. If you generate the airfoil shape on a CAD system, and then send the computer diskette to a *laser cutting service*, they will be able to cut you templates that are accurate to 0.005 inches or better. This is far better accuracy than you are likely to achieve with hand filing. The preferred CAD software seems to be AutoCad. I've had this done, and the cost is only $ 30.00 per template, beautifully cut out of stainless steel. To find a laser cutter, look in your local yellow pages. There are numerous shops in all of the major cities.

3.2 WINGLETS

It can now confidentally be said that the time for winglets has finally arrived. With new commercial airliners like the Airbus, and Boeing 747 sporting winglets, it has been somewhat surprising that glider designers have been so reluctant to tackle the design of these 'little wingtip shovels'.

Winglets were invented by Dr. Whitcomb at NASA Langley for use on commercial jet aircraft, and then later tried on sailplanes by German university students at Akaflieg Darm-

stadt, who reported that they didn't work too well. Wil Schuemann cut the tips off his ASW-12 and put on winglets to try to regain some performance, but reported inconclusive results. His feeling was that they really only worked on sailplanes that had tip flow problems to begin with. In the meantime the aggresive French company Centrair offered winglets as an option on their production sailplane version of the ASW-20. Although the availability of production winglets generated great interest in the late 1970's when they were first introduced, the interest waned when it became apparent that these winglets had a high speed loss which often outweighed the low speed gain.

A chance contact with Dr. David Marsden rekindled my own interest, and Ron Tabery and I built a variety of sets for the Nimbus III, in preparation for the world gliding contest in 1989. The positive experience gained in that contest, and subsequent confiming wind tunnel tests led to versions being adapted to the Ventus, Discus, DG-600, and ASW-20. (see figure 3-3).

The measured performance gains have ranged from 2.1 points to 3.8 points. In the world championships in Uvalde, Texas, ten pilots flew with these winglets. It was very satisfying to see that the highest overall speed in the contest went to a Ventus with my winglets - not to an open class ship! On the same day, where the winning speed was 155 km/hr, the top five contestants in the 15-meter class were sporting winglets. This is good experimental evidence that the winglets are not hurting the overall ship performance at high speed, as has often been pointed out by sceptics.

Winglets enhance max L/D particularly at the low speed end, by spreading out the downwash field behind the wing. Since this is equivalent to extending the span, the winglets in part reduce induce drag in the same way as a span extension. The added surface area of the winglet adds to the skin friction drag, and there is some point where the friction drag of the winglet exceeds the drag reduction provided by reducing the induced drag. This is commonly called the cross-over point. For the various sailplanes that we tested in still air, this speed is in the range of 80-90 kts unballasted, and 100-110 kts ballasted. Since these speeds are normally at the upper limit of cruising speeds that are flown, the potential penalty of the high speed loss of the winglets is outweighed by the lower and medium speed gain.

Carl Herold reported that the winglets on his big Nimbus III improved the roll rate from 14 seconds (+/- 45 degrees) to 9 seconds at thermalling speed, although this comparison was based on comparing the long span version against the short span machine with winglets.

The maximum roll rate of a sailplane is primarily limited by the angle of attack change that can be generated by deflecting the ailerons. Winglets increase the available lift at the tip and thus increase the roll rate. Therefore the roll rate change is a direct measure of the improvement in angle of attack capability at the tip. The additional angle of attack capability also means that the circling performance is inproved, as Carl Herold reported.

Other people that have tried winglets include Ray Gimmey, who used them on a Nimbus III (which *won* the Open Class nationals, and Ben Badenock, who had good success with winglets mounted on a PIK-20 (and built by Mike Maxwell).

In 1989, Ron Tabery and I built a set of winglets for the Nimbus III, which were used on my loaner Nimbus III in the last world championships. In contrast to Ray Gimmey's machine, we grafted them onto the end of the tip extensions for the Nimbus III. The results were very pleasing, both from the standpoint of practical experience with the winglets and the

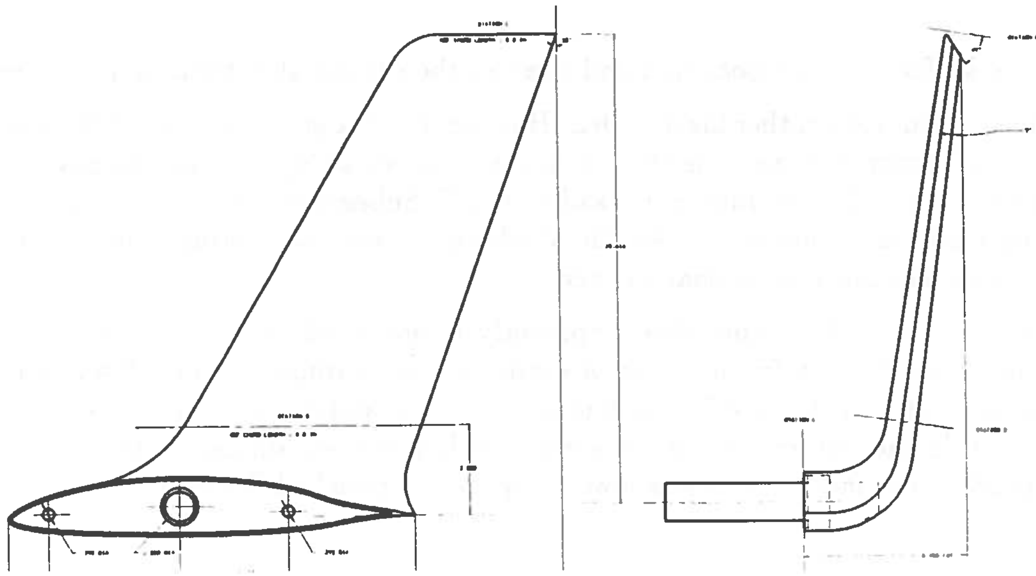


Figure 3-3. Successful Winglet Configuration.

subsequent wind tunnel tests. The roll rate of the big 24.5m Nimbus improved approximately 20 %, and no tip stalling problems were evident. Wind tunnel tests confirmed the performance gain. In a direct L/D comparison of the normal Nimbus tip and the tip + winglet, an L/D increase of 8% was achieved. The high speed performance penalty was not evident except at very low angles of attack - equivalent to approximately 110 kts with full water (9.5 psf). The data is reproduced in figure 3-4. It is difficult to translate this data to the actual flight polar of the sailplane, so additional tests would be required to define the actual performance gain when mounted on the sailplane.

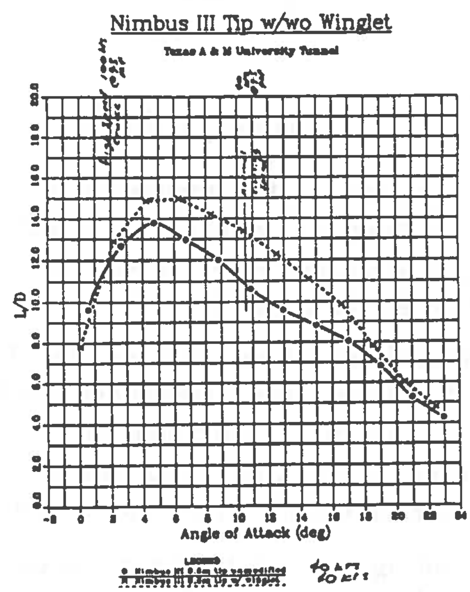


Figure 3-4. Winglet Wind-Tunnel Tests

3.3 RIBLETS

Riblets are a special adhesive backed plastic film now being marketed by 3-M company as *low drag skin reduction film*, for use on sailboats. The idea is that you apply the material

to the surface of your boat hull and presto - the surface skin friction drag is reduced !

This seemed like a rather bizarre idea. However it got a great deal of publicity recently when Dennis Conner, representing the US in the America's Cup, claimed to have used a special secret coating of riblet film on his sailboat hull. Subsequent to that, it was announced that Boeing Aircraft company in Seattle Washington was considering using some variation of this idea on their commercial jetliners.

The principle behind this idea, apparently is borrowed from the animal kingdom. It is known that the skin friction drag of sharkskin, for example, is lower than it might be for a smooth material. In an effort to find out why, researchers at a Germany university picked up on this and determined that a surface with a grooved surface, with the grooves aligned parallel to the flow, can have a lower drag than a polished flat surface (figure 3-6).

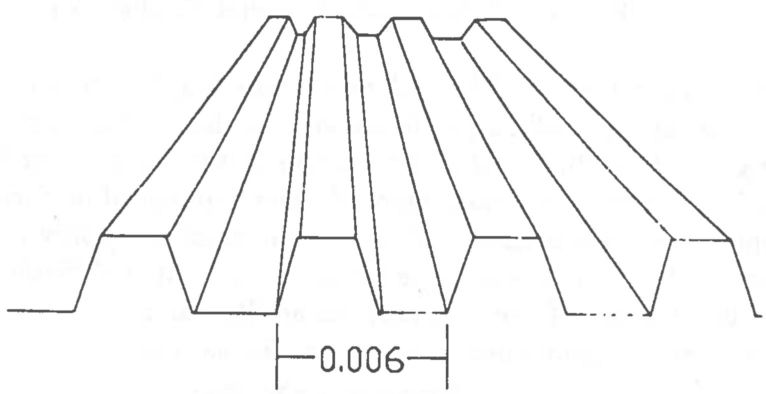


Figure 3-5. Riblets

The optimum groove spacing and depth depends on the local Reynold's number. If it is not sized correctly, then the drag will be higher ! Typical groove spacings are in the order of thousanths of an inch, so you can't see them very easily. The surface of the riblet film looks something like the surface of a record.

In any case, I was determined to find out whether this idea might work on sailplanes, so I called 3-M and arranged to have some material delivered for testing. At the same time, a group of students at the University of Michigan offered to run the tests, provided that I supplied the materials. I built them a full sized cross section of an ASW-20 wing (4 foot span, 30 inch chord) to insert into their large wind tunnel.

The results were disappointing, in that they were inconclusive. The drag rake used to measure wing drag did not have enough resolution to see the difference. The data scatter in the results was too high.

More recently, Joe Coram, a graduate student at Texas A & M university has conducted some drag measurements on a symmetric airfoil section. He used sophisticated hot wire anemometers to measure the flow velocities behind the wing, and determined that indeed an 8% reduction in skin friction drag was measured (under optimum conditions). Significantly, he found that the riblets were not very tolerant of flow angle - they had to be aligned with

the flow within +/- 5 degrees.

Sandy Bassett and Klaus Holighaus have tried riblets on the Discus. They did not report any favourable results. I have learned of late that riblets must only be used on the fuselage and not on the wing ! The reduction in vorticity in the boundary layer that the riblets cause leads to the a loss of energy that the airfoil designers counted on to help keep the flow attached to the wing.

It appears that the best application of riblets would be on the fuselage behind the wing root. The flow on the tailcone is reasonably predictable and normally aligned with the tail cone at all but high lift conditions. The riblet film spacing should be chosen so as to optimize it for high speed flight conditions where the turbulent skin friction drag is significant.

3.4 BUG WIPERS

The performance of modern laminar airfoils is severely degraded by the accumulation of foreign debris on the leading edge of the sailplane wing. Debris such as insect strikes on the leading edge will result in a significant increase in drag, as the result of premature transition to turbulent flow and increased friction drag.

Both the high and low speed portions of the sailplane polar are adversely affected. The relative increase in drag due to insect accumulation has been simulated and measured for different sailplanes using a standard disturbance pattern and a density of 20 bugs/meter. This bug density is probably most representative of eastern/central US conditions. In places such as Europe, the densities can approach 100 bugs/meter after a long flying day.

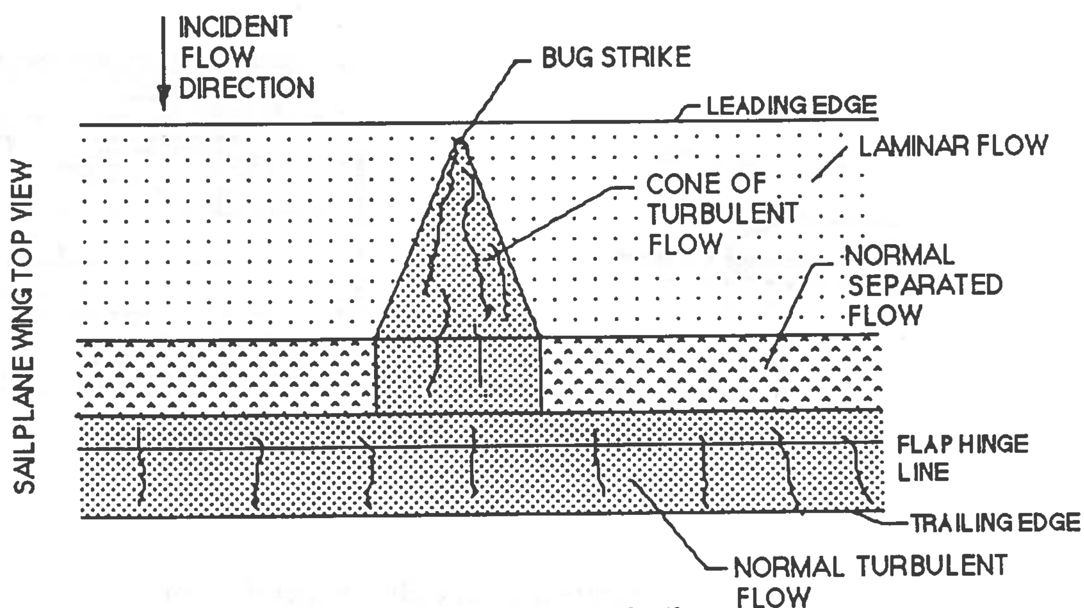


Figure 3-6. Simulated Bug Strike

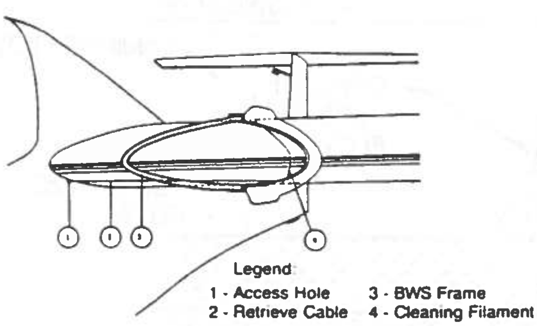
Figure 3-7 shows the results of a bug strike on the boundary layer. This is a top view of a laminar flow wing inserted into a wind tunnel with flow visualization achieved by smearing the wing surface with a liquid. The bug stike forms the apex of a turbulent flow region, which spreads back and enlarges at approximately a 20 degree included angle. The result is that only a few bugs near the leading edge are required to cause virtually the entire wing to prematurely transition into turbulent flow.

Sailplane	Max L/D clean	Max L/D 20 bugs/meter
PIK-20	38.0	29.5
Glasflugel 604	48.5	36.0
LS-3	41.8	34.4
Std. Cirrus	35.9	34.5
Mini-Nimbus	38.8	36.1
Nimbus II	47.4	38.4
ASW-17	47.4	38.9
ASW-19	38.0	35.8
ASW-20	41.7	32.7

Table 3-1. Performance Degradation Due to Bug Strikes

Some airfoils are more sensitive than others to bug strikes, as the result of the variation in the spreading angle of the turbulent flow region. Additionally, the thickness of the airfoil affects the probability of striking bugs in the first place. Thinner airfoils are known to pick up less bugs. In tests run by Richard H. Johnson (and published in Soaring magazine), performance reductions of maximum L/D were reported for the following popular sailplanes.

Many novel ideas were tried and patented over the last two decades; none of which proved to be practical. For a time, rubberized leading edges were thought to offer an alternative. Other designs proved to be viable, but were not versatile enough as to be adaptable to more than one specific sailplane.



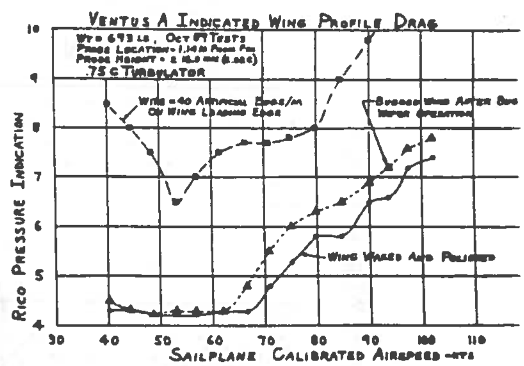


Figure 3-7. The Bug-Wiper-System

A new device has recently been developed in Austria which removes the bug accumulation from the wing and restores the original 'as-clean' performance level of the sailplane (figure 3-8). This semi-custom device consists of a cleaning device shaped to the leading edge of the wing, which when deployed traverses out on the wing from the root to the tip, and back. In its deployed position, the device folds open like a pair of scissors, and uses aerodynamic sideloads on the frame to pull it towards the tip. A very thin stainless steel wire attached to the framework of the bug wiper wraps around the leading edge and cleans off the body

of the insect, leaving only a small blood stain. A small synthetic fiber strand is attached to the bug wiper, and this is used to pull the device back from the wing tip to the root, where it folds up and retracts against the fuselage or wing root fairing. In one variation of the bug wiper system, small DC motors inside the sailplane allow the device to be deployed or retracted with an in-cockpit switch. Each cleaning sweep takes approximately 45 seconds/cycle. A manual spooling system is also provided in the event of battery failure.

The drag penalty of the device in the retracted state is very low, since it is positioned in the turbulent boundary layer at the wing/fuselage junction. Certainly the potential drag increase of the device is considerably lower than having more than a few insects accumulated on the leading edge.

The most recent world championships confirmed the effectiveness of the bug wipers. With approximately 25 % of participating pilots using the devices, each of the three new world champions turned out to be bug wiper users. With 50 % of pilots in open class using the device, all top ten pilots used bug wipers !

3.5 TRIM DRAG REDUCTION THROUGH ELEVATOR RESHAPING

The elevator of the Nimbus III includes a small undercamber, which is designed to force the elevator trailing edge to lift at high speeds. This provides an automatic trim effect which makes it difficult to overspeed the sailplane. As you increase speed, you must apply higher and higher forward pressure to maintain speed. This modification was dictated by the German LBA authorities, however it was not a part of the prototype Nimbus. I'm not sure which is safer. With the elevator undercamber, if you are going fast and your hand slips off the control stick then the wings break off because of the sudden back stick motion. With no elevator undercamber, you may inadvertently overspeed if you are not observant and don't notice that you are past redline.

In any case, the solution is to remove the undercamber on the elevator (figure 3-9). This provides slight additional performance, since the lack of lift generation on any surface implies less drag.

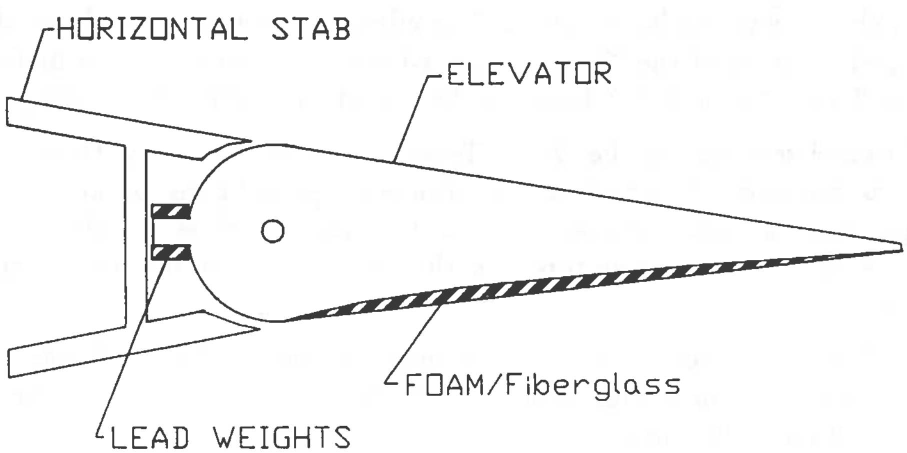


Figure 3-8. Removing Elevator Undercamber

To do this you need to fill in the undercamber on the bottom surface. However before doing that, check the mass balance of the system. Remember that the elevator may not appear to be completely mass balanced when checked at the hinge line since the vertical control rod mass attached to the drive belcrank needs to be taken into account.

Having determined the mass balance, sand off the gel coat and bond a layer of foam to the surface with epoxy (*Foam is available from Aircraft Spruce and Supply, Fullerton, CA*). After curing, sand the foam down such that it forms a flat surface between the leading and trailing edges of the elevator underside. Lay up a light layer of fiberglass with epoxy resin over the foam. Please, don't use polyester resin ! Sand ,fill, and paint as appropriate.

Before reinstalling the elevators, you must rebalance the elevator. You will need to add lead weights to the front of the elevator to avoid flutter problems. Pop rivet 3/32 inch lead sheet to the front of the elevator and verify the mass balance as necessary.

3.6 WING ROOT AND TIP FILLETING

The state of the art in wing-root and wing tip design is embodied in the LS-4, LS-6, ASW-24, and the latest Nimbus III's. These aircraft have been refined from previous designs like the LS-3, ASW-20, and Ventus whose climb performance suffers from separated flow at the wing root at thermalling speeds. Dick Johnson discovered this on the LS-3 and found that the addition of a flap seal wiper helped cure part of the problem. However the fact is that many of these earlier ships have flaps which come too close to the root, and the air already disturbed by the fuselage is unable to take the bend over the flaps and separates instead. Flap fences due not cure this problem.

Figure 3-10 shows some photographs reproduced from an article written by Dick Johnson on the PIK-20. You can easily see the tufts at the wing root fillet which are showing reversed or separated flow, even though the main wing is still flying.

Rick Wagner in Tehachapi, CA has done extensive flight testing on the ASW-20, and has taken photographs of a tufted ASW-20 wing root from a tail boom camera. His solution was to extend the wing root fillet, and to cut out approximately 4 inches of flap and reattach it to the wing root (figure 3-11). This makes it similar to the production version of the LS-6, which is known to have outstanding climb performance. Additionally, Rick cut off the drooped wing tip of the '20 and replaced it with a swept up and more highly tapered tip (figure 3-12). Again this follows the designs of the more recent racing sailplanes.

In wind tunnel research on the '20 at Texas A and M university, Oran Nicks found that a sharp tip was more effective than the drooped tip configuration at high lift coefficients. Oran's premise was that the sharp tip was less likely to allow circulation to develop from the bottom of the wing to the top, and thus would tend to inhibit the generation of the wing tip vortex.

Schempp-Hirth most recently has been selling a retrofit kit for the Nimbus III and Ventus, which in essence is a new wing root fillet. It fits like a glove over the fuselage and wing, and is glassed and faired in place.

Wing root and tip modifications are not trivial undertakings. Before embarking on a major project such as this, you would do well to do some tuft testing first to determine whether you have a problem in the first place and how extensive it is. This is best done by mounting a remote camera on the tail dolly and shooting some in-flight photographs of the area of

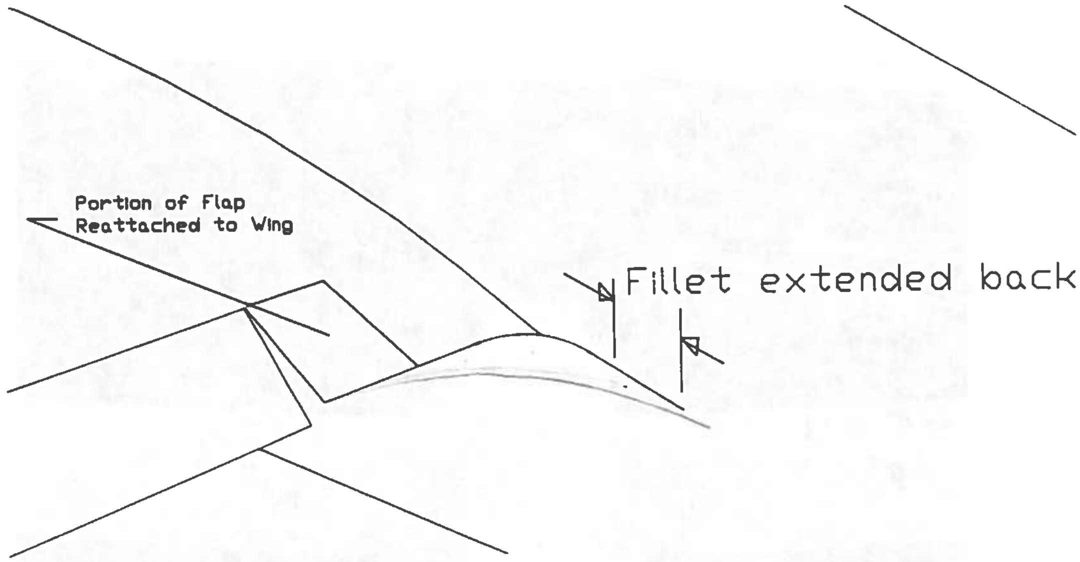


Figure 3-9. ASW-20 Root Mods

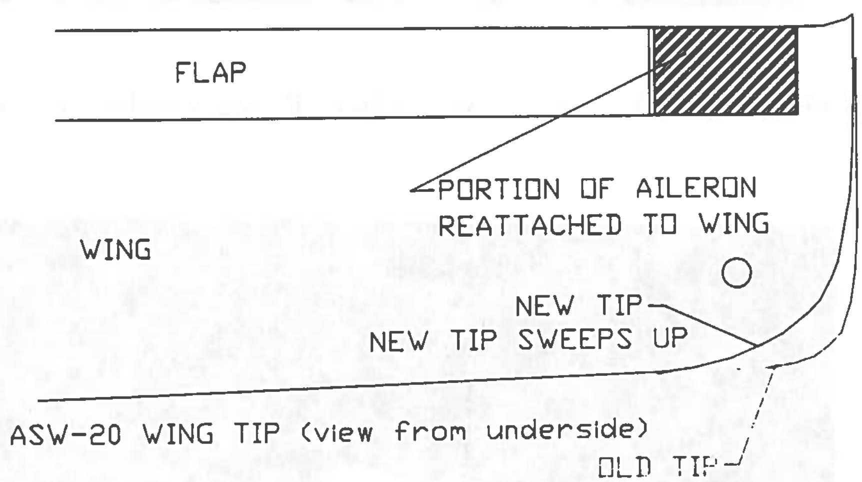


Figure 3-10. ASW-20 Tip Mods

interest.

Having determined that a problem exists, it would then be best to try some vortex generators at the root first since these are so easy to make and install. They should be put just in front of the area of separated flow, as determined from the tuft testing. Subsequently, if this proves to be beneficial, one can then go all out with a root fillet modification.

The success of Rick Wagner's modifications on the ASW-20 are dramatically illustrated in the before and after series of photographs. Comparing the tuft alignment at 45 kts, with thermalling flap position in the before (fig 3-13) and after (fig 3-14) shows a remarkable improvement. The crossflow at the wing root with the flap deflected was eliminated after modifications were made. This resulted in an improvement in climb performance for the modified ship.

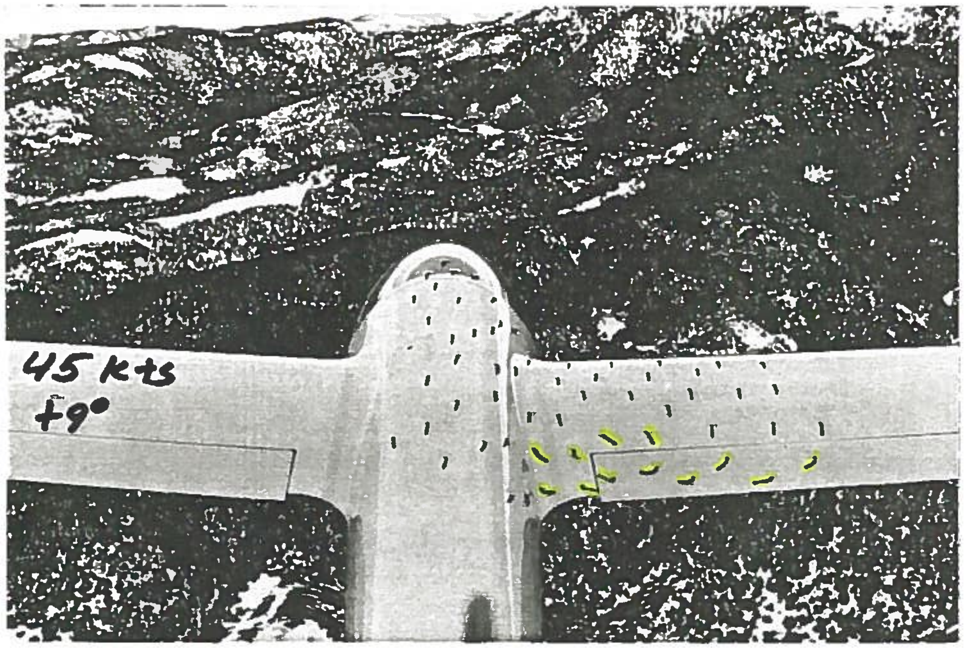


Figure 3-11. Airflow at ASW-20 Root Before Modification (45 kts)

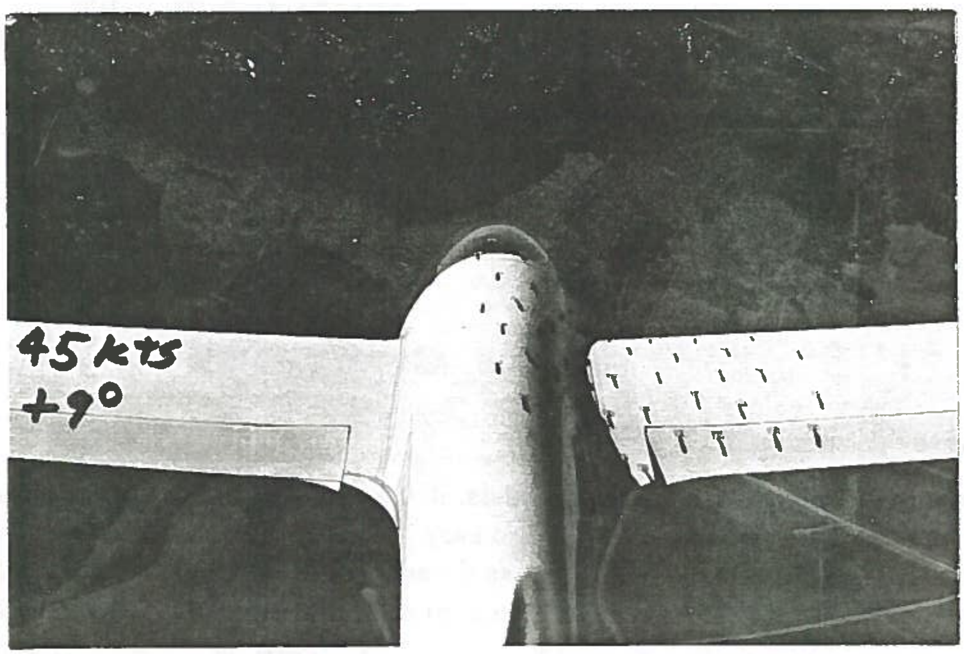


Figure 3-12. Airflow at ASW-20 After Modification (45 kts)

3.7 TIP AND TAIL TANKS

Tail tanks are now standard on all of the newest racing ships - the DG-300, Discus, and LS-6, etc. The addition of water ballast into the leading edge of the wing moves the center of gravity forward from the normal unballasted position. To counteract this center of gravity shift, ballast is added into the tail tank.

You can easily tell whether your C of G is optimum in flight. If you are thermalling with the trim lever set all the way back, then you need to move your C of G back, otherwise you will experience drag increases from two sources: a) the tail has to push down to keep the nose of the sailplane from dropping, b) the wing has to generate even more lift to make up for the downward load on the tail. The trim drag from the tail is therefore compounded by the added induced drag from the main wing.

Whatever you do, if you put in a tail tank, don't go out and add so much water so as to put the C of G behind the aft limit. There's no point in doing this - you don't gain any performance, the airplane becomes very squirrely, and you will probably kill yourself if it stalls and drops into an unrecoverable flat spin.

As Dick Johnson pointed out in a recent article in Soaring, the combination of a very heavily ballasted ship, with a low tow-hook position and tail ballast is extremely dangerous in gusty turbulent air. The pitching up moment generated by the towrope pulling from below the sailplane C of G can force the nose of the sailplane up. This pitch up moment may exceed the available lift (and pitch-down moment) that the elevator could generate. If the tail stalls on tow, you are toast. This is not theory - it happened to a well known contest pilot who is no longer around to talk about it. He overballasted and paid the price of ignorance.

Have you ever had the experience of flying around with one wing full of water and another completely empty ? If your sailplane has rubber water bags instead of integral water tanks then this has probably happened to you. In turbulence, water bags may twist, in which case the fill/dump outlet may be closed off.

It is rather surprising, however the assymetric load due to having one wing full of water and another one empty is normally only noticeable at circling speeds. On landing you probably won't notice anything until you flare and touchdown and then find yourself unable to keep the wings level on the rollout.

I had the experience recently (unplanned) of flying with one wing entirely full of water and another completely empty on a very weak day. Once I realized what had happened, I took advantage of the situation and decided to make it into a little experiment. It was quickly apparent that the achieved climb rate in one direction was considerably better than the other. For example, with the right wing completely full of water (about 110 lbs) and the other empty, one was able to fly the ASW-20 several knots slower and climb better to the left as compared to the right.

In a turn, the inside wing travels slower than the outside wing, and thus must fly at a higher angle of attack to maintain a constant angle of bank. In practice this is done by applying aileron pressure to the outside of the turn to keep the inside wing from dropping. At circling speeds the inside wing is normally very near stall, which means that it is operating outside of the low drag bucket. This increases the drag and lowers the effective L/D.

A second contributor to drag increase is the fact that the normal optimal elliptical lift distribution is distorted by the application of ailerons. This results in an increase in in-

duced drag. Therefore a redistribution of spanwise load in a turn can improve the climb performance (figure 3-15).

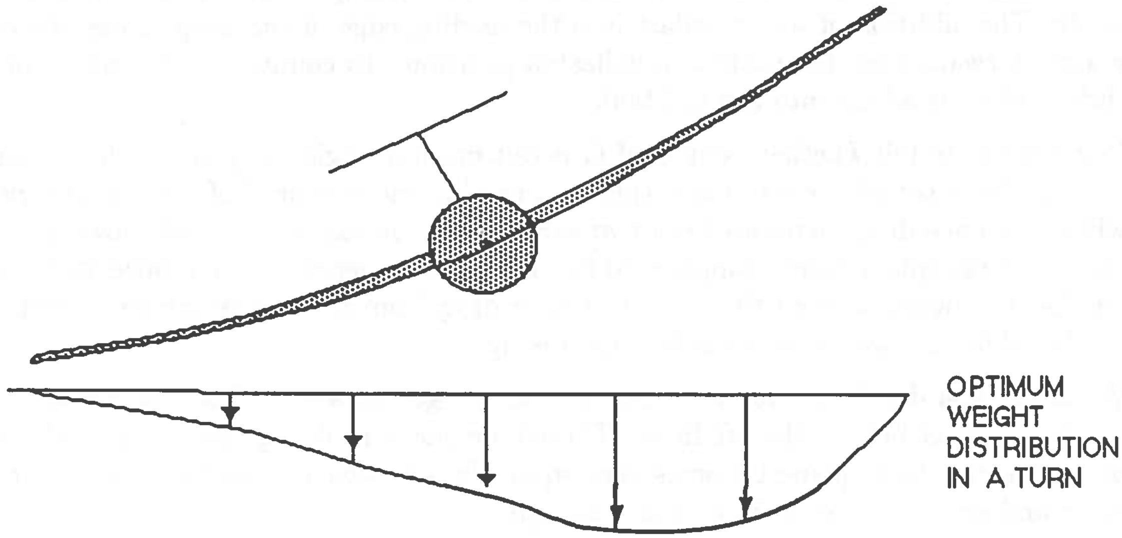


Figure 3-13. Shifting the weight distribution in a turn

There may be some value in building special tip tanks which would allow water to be pumped into them to redistibute the water load while climbing. Since I haven't tried this, I can't comment on the practicality of the idea. It does seem however that safety would not be compromised. If you were in a right turn, then if you stalled out and dropped into a spin, the spin would logically go to the right. With extra weight in the left wing however, it would seem that spin recovery to the left would not be hindered.

3.8 AUTOMATIC FLAPS

It has been known for some time that the achieved cruise speeds of pilots flying cross-country has been considerably higher than predicted by pure Macready theory. My recollection is that the maximum speed that you are likely to achieve using traditional circle/cruise techniques is about 67% of your cruise speed as defined by the Macready ring. Therefore if it is a 5 knot day, and you cruise at 100 knots between thermals (as defined by the Macready ring), then your achieved cruise speed is likely to be approximately 67 knots, or 67% of 100.

Pilots that use modern glide computers have the ability to record the percentage of time spent cruising, and the percentage of time spent climbing. I have observed at contests that several pilots have reported on days where no cloud significant cloud streets were encountered that their percentage of time spent cruising was indeed very close to the 67% figure previously stated.

Some pilots however who fly long span open class machines have reported cruising percentages in the range of 90% and above (Ray Gimmey and Carl Herold for example), *on exceptional days with streeting.*

An interesting paper written by Wolfram Gorish at Akaflieg Munchen supports the theory that pilot's are achieving higher cruising speeds than predicted by Macready analysis by using dolphin soaring techniques. Gorish's paper predicts that there is an optimum flight

profile for thermal entry and exit. He predicts an optimum 'g' load to pull on entering and exiting a thermal. These optimum 'g' loads are in the neighbourhood of 0-2 g's.

To enable optimal execution of dolphin flight, frequent pitching motions and 'g' load changes are necessary. Other designers have predicted that it is more efficient to use flaps than elevators for this, *provided that the movement of the flaps does not upset the trim balance.* In theory, the higher the 'g' load, the more the flaps should be applied. Also, the higher the speed, the less the flaps are necessary.

A system has been devised for the LS-3 and the MU-28 aerobatic sailplane that automatically senses speed and 'g' load, and applies the appropriate amount of flaps for the flight condition (figure 3-16). Therefore, when you move the control stick forward, this reduces the 'g' loading and the speed increases. The control mechanism senses 'g' loading via a weight system, and applies less flap via a fulcrum attached to the flap lever. As the speed increases, the trailing edge of the flaps want to move upward which also happens to be optimum. They move upward until a spring in the system balances the applied force and equilibrium is established.

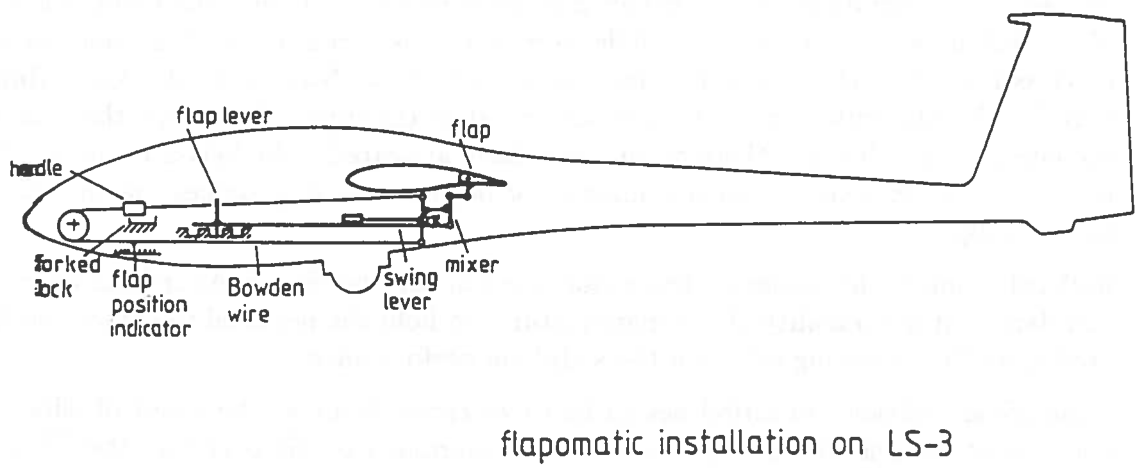


Figure 3-14. LS-3 automatic flap system

This type of system is very complicated for the average tinkerer and should be left for those persons with the appropriate engineering background. It may be prone to flutter, however the fact that it has been demonstrated in two examples of modern sailplanes proves that it can be done safely. If you are interested in implementing the system, contact one of the students at the Akaflieg Munchen. I have seen the system, and it really is quite straightforward to install on the LS-3.

3.9 NEW AIRFOIL SECTION

It may be obvious to the reader of this article that the *labour intensive mods* have been organized in order of degree of difficulty. One modification that would very likely work, and produce a significant gain is a new airfoil section gloved onto your existing wing. This however is at the expense of a very significant amount of labour. To have confidence that these efforts would be fruitful, one needs to understand something of the history of laminar

flow airfoils as used on sailplanes.

Practically all of the successfull fiberglass sailplanes in production since the middle 1960's have used Wortmann airfoils. The really big advances came in 1960-1962, where Wortmann designed the airfoils that were later used on the ASW-12/17/20 (FX-62-K-131 mod) and the ASW-15/19 (FX 60-126).

Wortmann's remarkable contribution to the science of airfoil design was the extension of knowledge of into the low speed end of the spectrum. Whereas much of the scientific community had focussed all efforts on high speed flight, Wortmann turned his attention to the problems of low speed flight. This required a better understanding of viscous effects, transition ramps, and boundary layer development at low Reynold's numbers.

Other sailplanes like the Libelle used older Huetter airfoils. Wil Schuemann discovered that the Huetter airfoil was very similar to the Wortmann airfoil with the exception of the leading edge area. He cut off the leading edge and glassed in a new leading edge in front of the spar so that the profile almost duplicated the Wortmann airfoil. This was a very successfull modification, and was copied by many H-301 Libelle owners in the United States.

Subsequent attempts to design better airfoils floundered. Even Wortmann's 1967 design of the FX 67-K-150/170 series airfoils were not considered in the final analysis to be as good as his 1962 airfoils. These airfoils were used on the Nimbus II, the Mini-Nimbus, the PIK-20, the Mosquito, LS-3, DG-200, and most of the other 15-m ships that came out in the late 1970's. Although these airfoils may have appeared to be better in the wind tunnel, they were rather sensitive to manufacturing defects and bug strikes, particularly at the leading edge.

Richard Eppler who designed the airfoil section for the Speed Astir blamed its lack of popularity on the inability of the manufacturer to hold the required tolerances on the wing profile, and its resulting effect on the sailplane performance.

A significant advance in airfoil design however came about as the result of efforts by two students at Braunschweig University in West Germany to discover why the SB-11 wasn't performing as well as predicted. They located and documented the existance of a laminar separation bubble on the bottom surface of the wing, and researched a means for eliminating it. The drag of the separation bubble was known to be much higher than the drag of the same section of wing in turbulent flow.

From this research, the idea of turbulators and blowholes was born. The turbulators reenergize the boundary layer (at a small drag penalty), and cause direct transition from laminar to turbulent flow. The overall drag coefficient for the airfoil is reduced somewhat, particularly at high speed.

Some newer airfoils were then deliberately designed to take have a laminar separation bubble on the bottom surface, which would then be eliminated with turbulators or blowholes. Examples of this technique are reflected in the production version of the ASW-20B/C, the ASW-22, and the popular DG-300.

Most of these newer "turbulated" airfoils have been designed by the same two university students who did the original research - Horstmann and Quast. Their HQ airfoils are now used almost exclusively by all of the German sailplane designers, with good reason. Their performance based on competition results and flight test characterizations is markedly

better than the older Wortmann airfoils. Each of the sailplanes that won their class in the last world championships (the Discus, ASW-22B, and LS-6B) used have used one of the newer airfoils (although only the ASW-22B is an HQ foil). The ASW-24, 26, and 27 use turbulated airfoils designed by Luke Boermanns of Delft University in Holland.

The success of Horstmann and Quast can partially be attributed to the use of an in-flight wind tunnel to make their measurements on their new airfoils. They have a special Janus which is outfitted with a platform above the fuselage for mounting a wing section. Data is recorded in-flight under real conditions.

Why is this so important ? It turns out that the turbulence level of most wind tunnels does not necessarily approximate the micro-scale turbulence experienced by sailplanes in flight. Therefore wind tunnel tests of airfoil sections are not necessarily comparable to real conditions, since the turbulence level has a significant effect on the development of the boundary layer. The use of this in-flight platform for flight testing seems to have paid off, as the newer HQ airfoils are clearly better than the predecessors.

This is particularly apparent when comparing the 'quasi-HQ-17' airfoil and the FX-62-K-131 (mod) as displayed in figure 3-17. The low drag bucket of the qHQ-17 is considerably extended into the high lift range (high Cl). I call it a 'quasi' HQ airfoil since the actual HQ-17 is proprietary, and these airfoil coordinates have been derived on a computer using the inverse technique based on published velocity distributions.

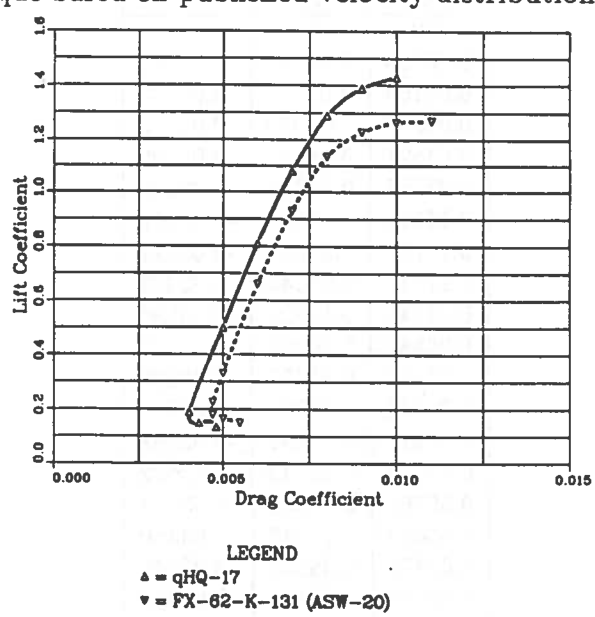


Figure 3-15. Performance Comparison of the Latest Generation Airfoils

Retrofitting this qHQ-17 airfoil to the ASW-20 would offer a major performance gain. Unfortunately, this effort would require unzipping the existing wing skins and reglassing entirely new skins around the spar and control system. When comparing the profiles of the 62-K-131 and the newer HQ airfoils, you can see that there is too much deviation between the two profiles to allow a simple fill job (figure 3-18). I am providing the coordinates here however for the sake of completeness and in the hope that someone out there with real determination might want to try it. (table 3-2).

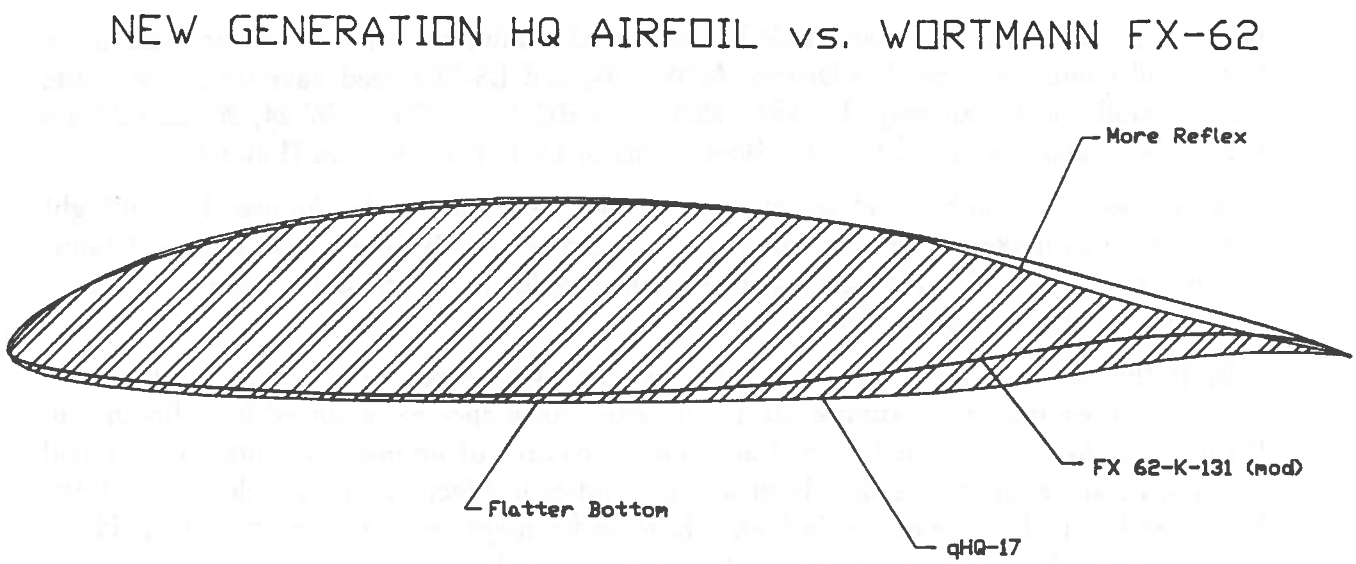


Figure 3-16. qHQ-17 Airfoil

Quasi HQ-17

X	Y_u	Y_l
0.0	0.0	0.0
0.00293	0.00717	-0.00668
0.01169	0.01731	-0.01227
0.02617	0.03070	-0.01773
0.04621	0.04445	-0.02229
0.07157	0.05824	-0.02612
0.10195	0.07123	-0.02939
0.13700	0.08307	-0.03221
0.17631	0.09345	-0.03407
0.21941	0.10220	-0.03536
0.26580	0.10939	-0.03647
0.31493	0.11477	-0.03699
0.36624	0.11800	-0.03704
0.41911	0.11891	-0.03688
0.47293	0.11743	-0.03632
0.52707	0.11359	-0.03524
0.58089	0.10743	-0.03360
0.63376	0.09858	-0.03145
0.68507	0.08654	-0.02846
0.73420	0.07214	-0.02356
0.78059	0.05748	-0.01639
0.82369	0.04426	-0.00869
0.86300	0.03298	-0.00263
0.89805	0.02362	0.00107
0.92843	0.01606	0.00272
0.95379	0.01014	0.00294
0.97383	0.00569	0.00233
0.98831	0.00256	0.00133
0.99707	0.00068	0.00045
1.00000	0.00000	0.00000

Table 3-2. qHQ-17 high-performance flapped airfoil

Chapter 4

MATERIALS AND SOURCES

4.1 EPOXIES AND HARDENERS

If you are structurally modifying a part of a certified aircraft, you are obliged to use the epoxy/hardener/glass system certified by the manufacturer. In many cases this will be a resin called *Epikote 162*, manufactured by Shell, used with a hardening agent called *Laromin C-260*, manufactured by BASF. These products are available for outrageous prices from your sailplane dealer, or can be purchased from the German source: *Lackfabrik Bader GmbH, Postfach 25, 7300 Esslingen, Germany.*

The irony is that the base epoxies are actually made in Houston, Texas by Shell Oil Company, and shipped overseas. There is some kind of trade restriction that prevents Shell from selling the same product directly to domestic customers (if you can figure this out please let me know). Apparently, importation of these epoxies into the US is a violation of federal law. I'm told that it may be related to the toxicity of the dilutant used with the epoxy.

The hardener, Laromin C-260 is made by BASF corporation and may be purchased domestically.

The technical support group at Shell advocates a newer improved epoxy system called DPL-862, which when layed up at room temperature and postcured to 200 deg F, provides a significant strength increase as compared to Epikote/Laromin. The key is the use of much less BGE dilutant (5 % compared to 18 % in the Epikote). The dilutant concentration lowers the heat deflection temperature of the layup, such that a postcured Epikote/glass wing will have a maximum service temperature of about 50 deg F less than the DPL-862/glass wing.

Martin Hollmann at Aircraft Designs, Inc, in Monterrey California has made and tested coupons using layups with different epoxy systems, and has verified that the DPL-862 resin is far superior to the Epikote system (which is chemically similar to another Shell product called Epon 815). The difference was so noticeable that Lancair switched their production line over from Epon 815 to DPL-862. I would advocate the use of this resin system along with hardener manufactured by Pacific Anchor Chemical Company (Ancamine 1769). For those homebuilders who use a brand of epoxy called *Safe-t-Poxy*, I would recommend that you change to the DPL-862 product. Hollman's tests showed that a layup made with this epoxy is very weak in comparison to the alternatives just described. The 862/1769/BGE chemicals may be purchased from Acme Distributors in Plano, Texas. You need to buy the

Sailplane Component	Weave	Weight (g/m^2)	INTERGLAS NO.
Fuselage	Twill Weave	161	92110
	Twill Weave	276	92125
Wings	Unidirectional	215	92145 skin
	Twill Weave	161	92110 skin
	Twill Weave	276	92125 spar root
	Twill Weave	390	92140 spar root
	Plain Weave	350	92150 spar root
Horizontal Stabilizer Elevators and Rudder	Unidirectional	215	92145
	Twill Weave	161	92110
	Twill Weave	276	92125
Flaps	Twill Weave	161	92110
	Twill Weave	276	92125
Airbrakes	Twill Weave	161	92110
	Twill Weave	390	92140
Ailerons	Twill Weave	161	92110
	Plain Weave	140	Carbon 02870

Table 4-1. Typical Glass Composition for a European Sailplane

base resin (862) and mix in the dilutant yourself (BGE). Use no more than 5% dilutant.

4.2 FIBERGLASS CLOTH

As in the case of epoxies, the glass cloth specified by the manufacturer must be used to repair any certified aircraft. Since these are European sourced, they will be expensive. The maintenance manual for your sailplane will provide a listing of recommended glass weaves and weights. Table 4-1 lists a typical material specification (in this case the Glasflugel Mosquito).

The above INTERGLAS products may be obtained from the manufacturer INTERGLASS TEXTIL GmbH, Soeflinger Str. 246, 7900 - Ulm/Donau., or from your sailplane dealer.

In the United States, there are a number of glass manufacturers and weavers of cloth. The most prominent cloth weaver is Hexcel corporation; they sell through a network of distributors in many of the bigger cities. One distributor in California is FRP supply. Their phone number is (714)-567-2706. Some of the popular styles are listed below in table 4-2.

4.3 FINISHES

Most of the glider repair shops in the United States are using a product called 'Polylux W-300-1' which is a good topcoat for refinishing work. It is a polyester based gel coat with a wax content that allows it to be air dried. In contrast, a true gel coat has no wax content, is relatively more viscous, and can be sprayed into a mold. The top coat is not well suited for building up significant thickness; thus if you are refinishing with Polylux, you may need to spray several times or spray on a sanding surfacer first to build up thickness. All of these materials are available from Polylux. Their address and telephone number are: Polylux

Style	Weave	Weight oz/sq yd	Width inches	Ply Thk mils	Tens Strength W x F (lbs/in)
EGLASS					
108	Plain	1.4	38	2	70x40
1522	Plain	3.7	50	5.5	156x143
3733	Plain	5.85	60	10	250x225
7715	Uni	7.2	38	9	
7725	BID	8.9	38	12.5	400x335
7781	Satin	9	50	9	350x340
7500	Plain	9.7	60	14	450x410
SGLASS					
500	Uni	12			
4533	Plain	60		7.5	300x275

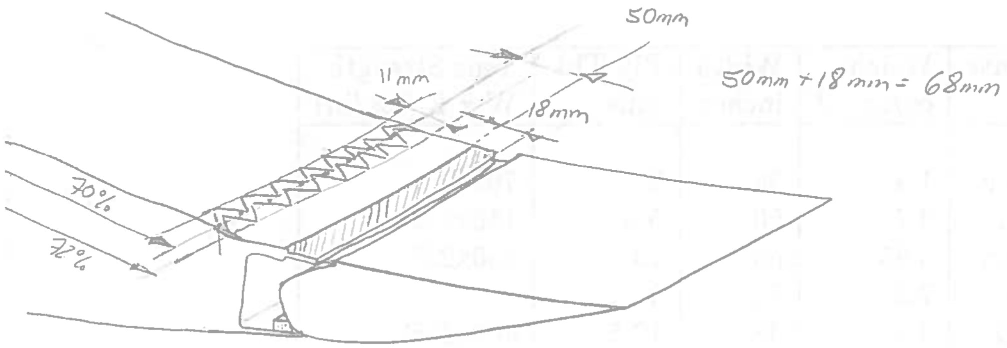
Table 4-2. DOMESICALLY AVAILABLE GLASS CLOTHS

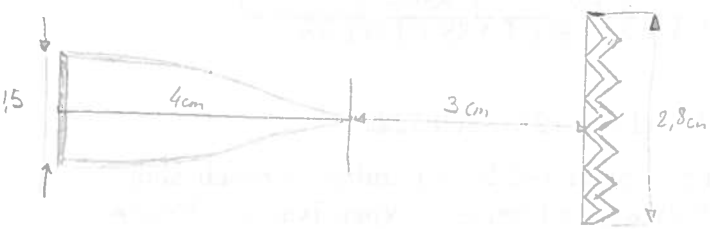
Inc., 1470 Spence St., Los Angleles, CA 90023. Tel # : (213)-269-7229.

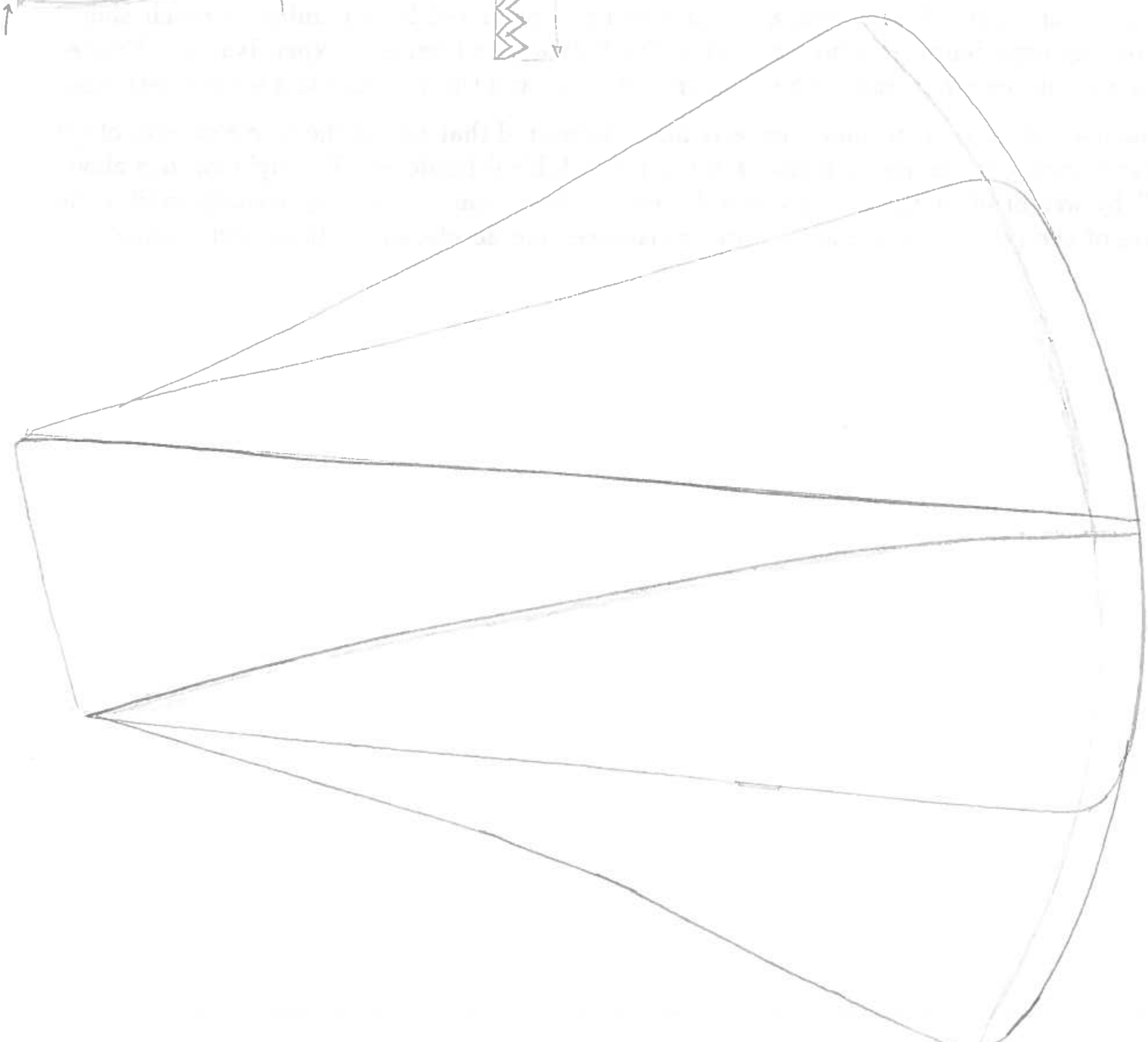
In previous years, *Prestec* was a product being popularized by a number of repair shops. From my experience. it is not as good as the Polylux, and twice as expensive. The Prestec tends to 'fisheye' very easily when you are spraying, and this can lead to a lot of frustration.

One note of caution: technical experts have discovered that one of the prime sources of gel coat cracking is the use by painters of too much MEKP hardener. The right ratio is about 2% by weight of catalyst, or about 8 drops/oz. Over catalysation may actually indibit the cure of the gel coat, degrade its water resistance, and accelerate chalking and erosion !

PUNTA : 50mm (60%)
MEDIO : 50mm (70%)
ENCASTRE: 75mm (70%)
(72%)





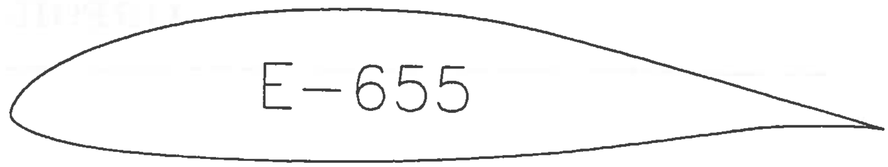


Chapter 5

AIRFOIL CATALOG

Airfoil	Where Used	Comments
E-655	Flapped Aircraft	High L/D ratio; good computer performance
79-K-144	Ventus/Nimbus III	Very low Cd, moderate Clmax
62-K-131	ASW-17/20	Robust airfoil, excellent performance
Discus	Standard Class	Outstanding Non-flappedd airfoil
60-126	ASW-20/Ventus tips	Poor performance
UAG-143/20	Flapped Airfoil	Conflicting Wind Tunnel Results
SM-701	World Class Sailplanes	Excellent Clmax
DU-80-141	Standard Class Tips	Good Low Re airfoil for tips

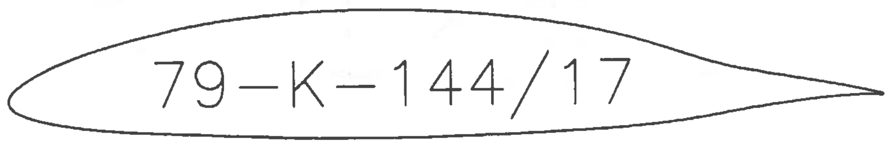
5.1 THE EPPLER E655 - 17.35 % FLAPPED SECTION



X_l	Y_l	X_u	Y_u
100.00	0.000	0.011	-0.173
99.632	0.092	0.024	-0.253
98.585	0.385	0.046	-0.328
96.960	0.868	0.077	-0.401
94.807	1.479	0.177	-0.474
92.127	2.196	0.165	-0.547
88.955	3.035	0.280	-0.694
85.360	4.000	0.421	-0.841
81.415	5.075	0.676	-1.061
77.197	6.236	1.644	-1.654
72.784	7.447	3.292	-2.319
68.250	8.660	5.447	-2.917
63.668	9.822	8.086	-3.438
59.100	10.847	11.184	-3.875
54.547	11.647	14.709	-4.227
49.975	12.199	18.625	-4.494
45.390	12.521	22.888	-4.667
40.816	12.635	27.451	-4.780
36.294	12.561	32.261	-4.805
31.873	12.315	37.262	-4.753
27.598	11.904	42.393	-4.626
23.512	11.339	47.592	-4.421
19.656	10.631	52.798	-4.129
16.066	9.793	57.954	-3.735
12.776	8.839	63.032	-3.211
9.815	7.786	68.040	-2.574
7.210	6.653	72.953	-1.883
4.981	5.463	77.725	-1.198
3.146	4.242	82.289	-0.584
1.719	3.021	86.554	+0.099
0.712	1.838	90.415	+0.223
0.138	0.741	93.764	+0.365
0.085	0.570	96.479	0.332
0.022	0.274	98.444	0.194
0.002	0.088	99.614	0.056
0.003	-0.089	100.000	0.000

Table 1: Eppler E655 17.35% flapped section

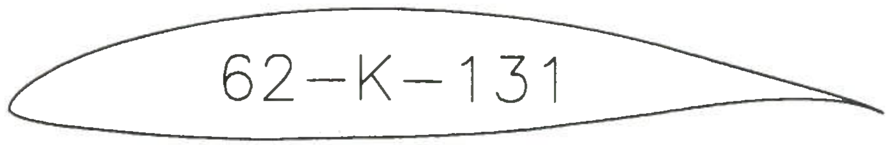
5.2 WORTMANN FX-79-K-144/17 - 14.4 % FLAPPED SECTION



X	Y_u	Y_l
0.0	0.0	0.0
0.00107	0.00480	-0.00430
0.00428	0.00990	-0.00870
0.00961	0.01510	-0.01250
0.01704	0.02060	-0.01590
0.02653	0.02650	-0.01920
0.03806	0.03270	-0.02230
0.05156	0.03910	-0.02520
0.06699	0.04540	-0.02790
0.08427	0.05160	-0.03030
0.10312	0.05770	-0.03250
0.12408	0.06370	-0.03440
0.14645	0.06950	-0.03610
0.17033	0.07480	-0.03760
0.19562	0.07990	-0.03880
0.22221	0.08480	-0.03990
0.25000	0.08910	-0.04080
0.27886	0.09260	-0.04160
0.30866	0.09550	-0.04240
0.33928	0.09780	-0.04340
0.37059	0.09920	-0.04370
0.40245	0.10000	-0.04370
0.43474	0.10010	-0.04380
0.46780	0.09930	-0.04370
0.50000	0.09770	-0.04330
0.53270	0.09560	-0.04250
0.56526	0.09270	-0.04160
0.59755	0.08880	-0.04010
0.62941	0.08450	-0.03840
0.66072	0.07980	-0.03640
0.69134	0.07350	-0.03430
0.72114	0.06580	-0.03190
0.75000	0.05690	-0.02880
0.77779	0.04780	-0.02470
0.80438	0.03970	-0.02030
0.82967	0.03340	-0.01570
0.85355	0.02930	-0.01170
0.87592	0.02540	-0.00840
0.89668	0.02200	-0.00560
0.91573	0.01880	-0.00330
0.93301	0.01560	-0.00160
0.94844	0.01270	-0.00030
0.96194	0.01000	0.00050
0.97347	0.00760	0.00100
0.98296	0.00570	0.00100
0.99039	0.00410	0.00080
0.99572	0.00280	0.00064
0.99893	0.00220	0.00010
1.00000	0.00200	0.00000

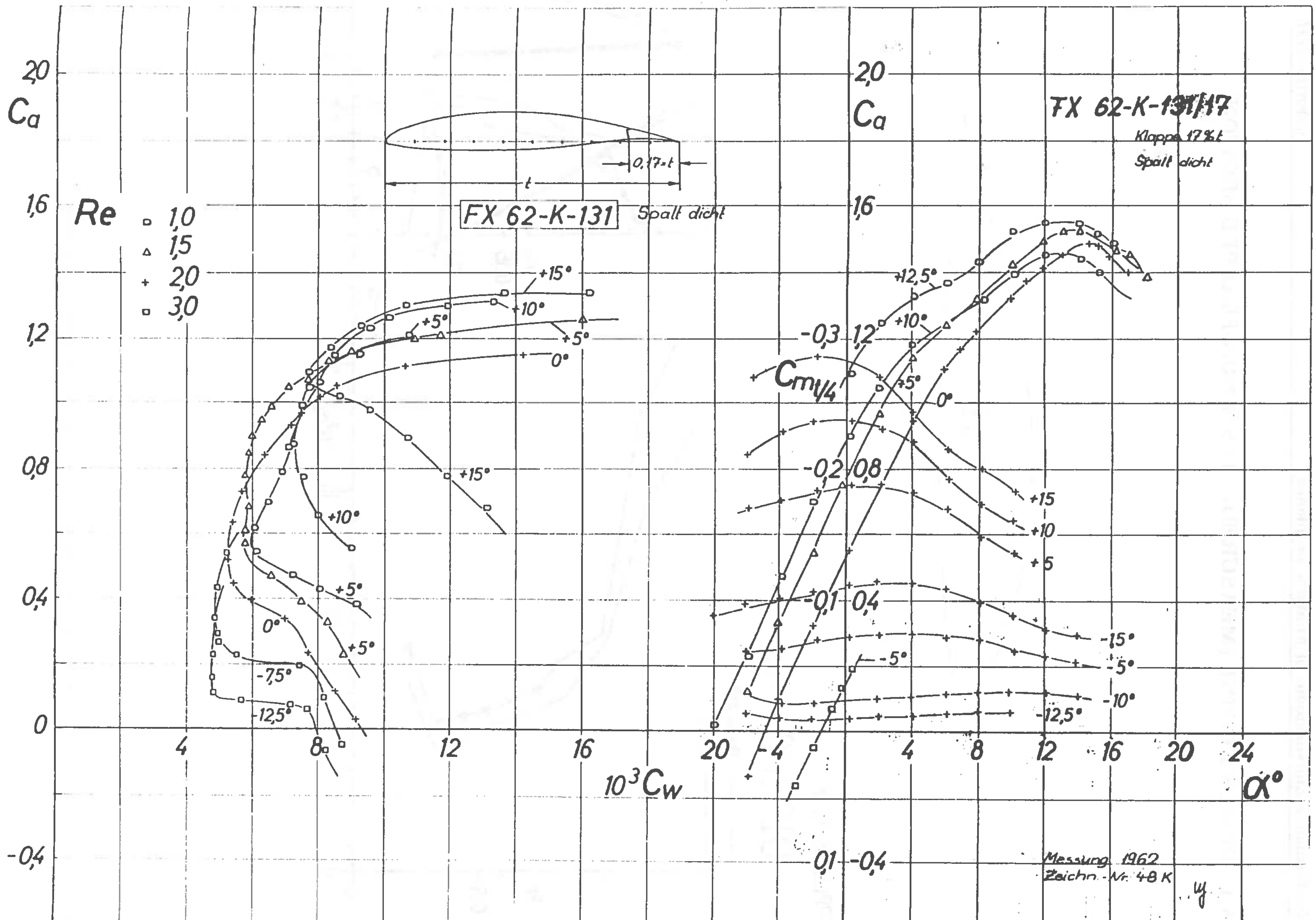
Table 1: FX-79-K-144/17: Ventus/Nimbus III airfoil at $\delta_f = -9.3°$

5.3 WORTMANN FX-62-K-131 (MOD) - 14.4 % FLAPPED SECTION



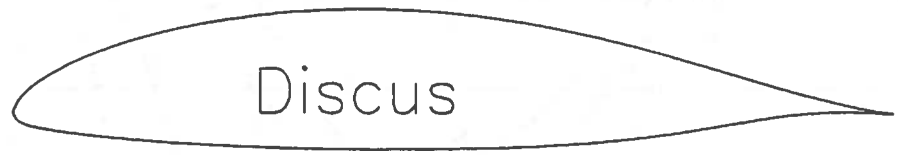
X	Y_u	Y_l
0.0	0.0	0.0
0.00102	0.00589	-0.00182
0.00422	0.01140	-0.00438
0.00960	0.01782	-0.00699
0.01702	0.02462	-0.00954
0.02650	0.03173	-0.01206
0.03802	0.03902	-0.01453
0.05158	0.04642	-0.01691
0.06694	0.05373	-0.01915
0.08422	0.06097	-0.02125
0.10330	0.06803	-0.02322
0.12403	0.07483	-0.02504
0.14643	0.08133	-0.02673
0.17037	0.08746	-0.02828
0.19558	0.09311	-0.02965
0.22221	0.09825	-0.03082
0.24998	0.10276	-0.03174
0.27891	0.10659	-0.03236
0.30861	0.10973	-0.03265
0.33933	0.11222	-0.03261
0.37056	0.11400	-0.03226
0.40243	0.11501	-0.03160
0.43469	0.11521	-0.03063
0.46733	0.11458	-0.02931
0.49997	0.11317	-0.02760
0.53274	0.11103	-0.02541
0.56525	0.10818	-0.02275
0.59750	0.10453	-0.01962
0.62938	0.10004	-0.01611
0.66074	0.09471	-0.01223
0.69133	0.08860	-0.00797
0.72115	0.08188	-0.00339
0.74995	0.07471	0.00129
0.77773	0.06739	0.00575
0.80435	0.06013	0.00966
0.82970	0.05313	0.01274
0.85350	0.04652	0.01496
0.87590	0.04031	0.01632
0.89644	0.03451	0.01687
0.91571	0.02912	0.01664
0.93299	0.02409	0.01573
0.94848	0.01940	0.01418
0.96192	0.01502	0.01210
0.97344	0.01095	0.00945
0.98291	0.00728	0.00659
0.99034	0.00434	0.00390
0.99571	0.00198	0.00165
0.99891	0.00040	0.00035
1.00000	0.00000	0.00000

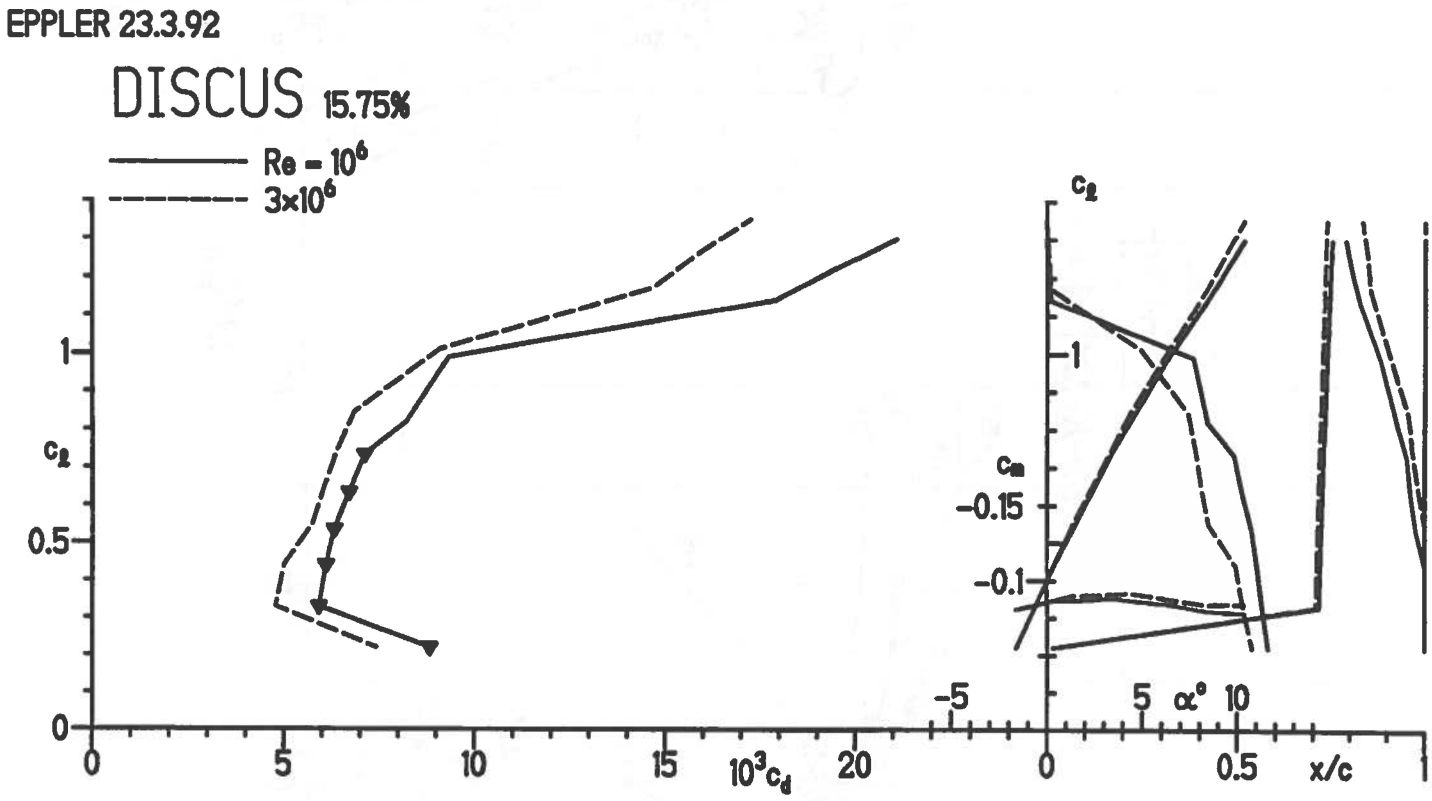
Table 3: ASW-20A inboard section, FX-62-K-131 *modified by D. Somers*



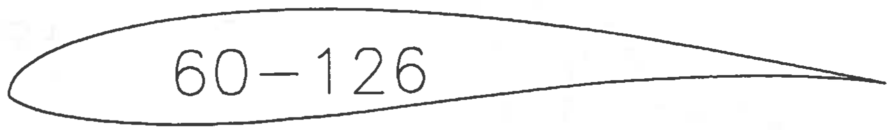
FX 62-K-131/17
Klappe 17% t
Spalt dicht
FX 62-K-131
Spalt dicht
0,17·t
t
Re
1,0
1,5
2,0
3,0
C_a
$10^3 C_w$
$C_{m t/4}$
α°
Messung 1962
Zeichn.-Nr. 48 K

5.4 DISCUS AIRFOIL (MEASURED) - 15.9 % NON-FLAPPED SECTION



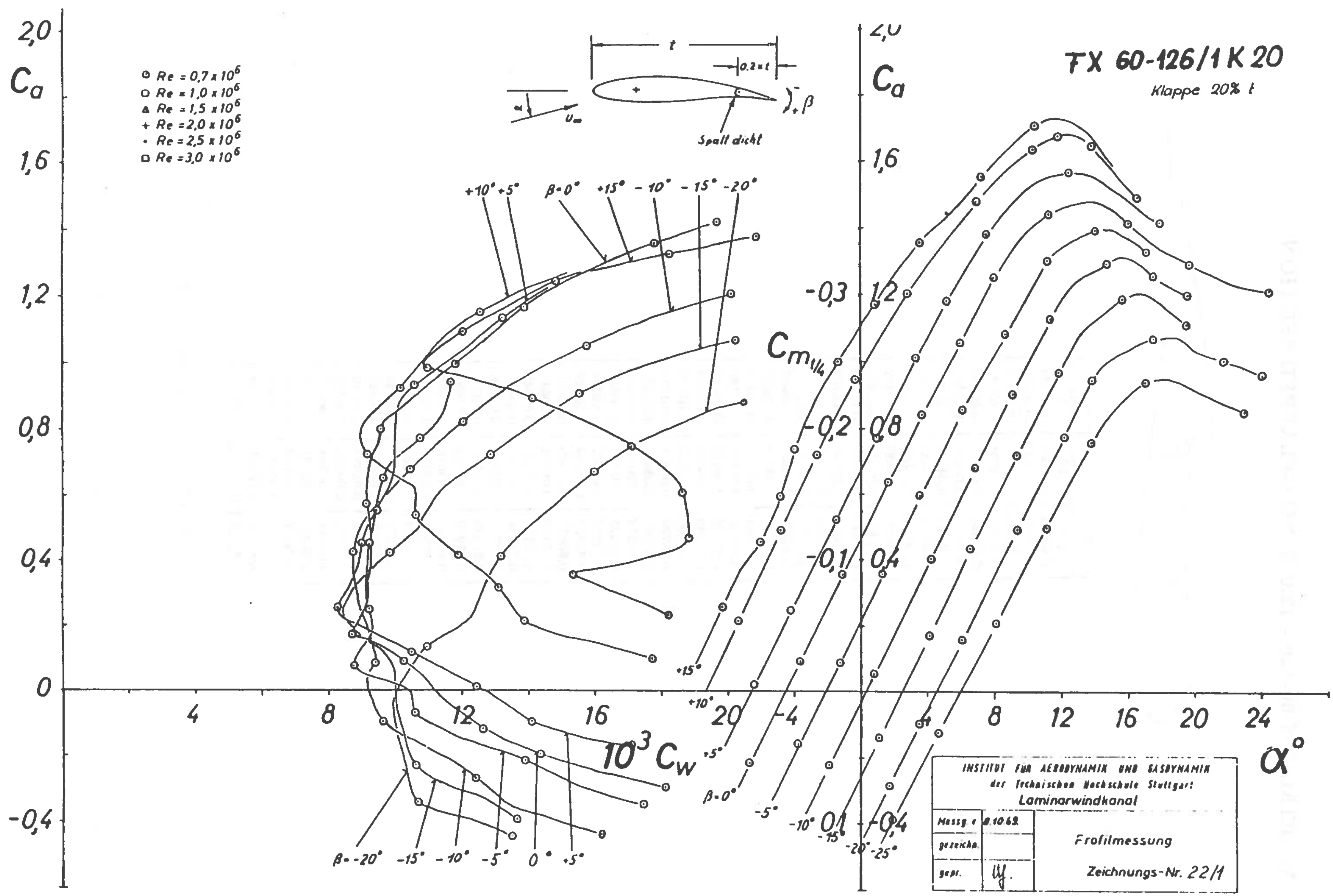


5.5 WORTMANN 60-126 - 12.6 % NON-FLAPPED SECTION



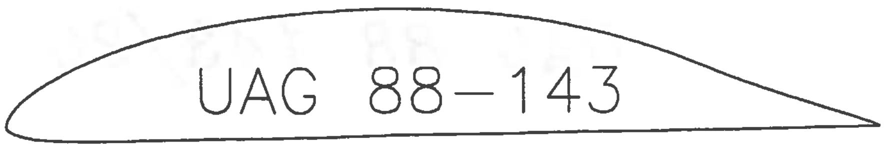
X	Y_u	Y_l
0.0	0.0	0.0
0.00102	0.00360	-0.00471
0.00422	0.01242	-0.00696
0.00960	0.02021	-0.01025
0.01702	0.02765	-0.01374
0.02650	0.03437	-0.01798
0.03802	0.04174	-0.02132
0.05158	0.04808	-0.02482
0.06694	0.05457	-0.02761
0.08422	0.06021	-0.03043
0.10330	0.06585	-0.03262
0.12403	0.07077	-0.03465
0.14643	0.07555	-0.03598
0.17037	0.07958	-0.03707
0.19558	0.08327	-0.03746
0.22221	0.08625	-0.03751
0.24998	0.08859	-0.03683
0.27891	0.09019	-0.03683
0.30861	0.09130	-0.03392
0.33933	0.09160	-0.03167
0.37056	0.09138	-0.02877
0.40243	0.09041	-0.02553
0.43469	0.08893	-0.02188
0.46733	0.08679	-0.01814
0.49997	0.08425	-0.01421
0.53274	0.08118	-0.01036
0.56525	0.07781	-0.00653
0.59750	0.07402	-0.00298
0.62938	0.06994	0.00029
0.66074	0.06549	0.00307
0.69133	0.06082	0.00547
0.72115	0.05589	0.00741
0.74995	0.05084	0.00897
0.77773	0.04567	0.01006
0.80435	0.04055	0.01073
0.82970	0.03552	0.01093
0.85350	0.03070	0.01074
0.87590	0.02611	0.01022
0.89644	0.02181	0.00944
0.91571	0.01777	0.00845
0.93299	0.01412	0.00732
0.94848	0.01084	0.00610
0.96192	0.00798	0.00483
0.97344	0.00554	0.00357
0.98291	0.00353	0.00239
0.99034	0.00198	0.00146
0.99571	0.00088	0.00068
0.99891	0.00024	0.00014
1.00000	0.00000	0.00000

Table 4: FX-60-126: ASW-20A tip section at 16.6m



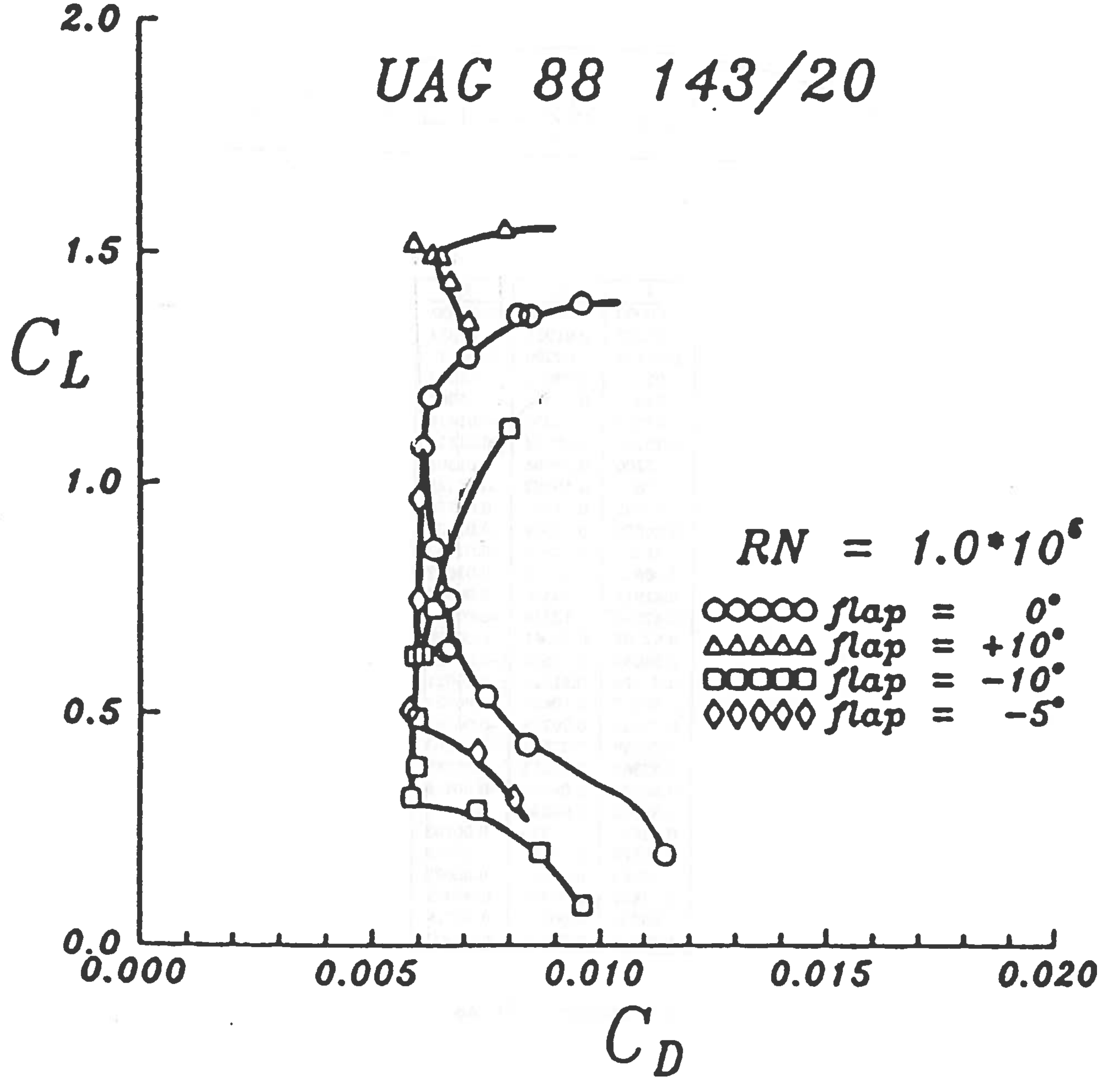
FX 60-126/1 K 20
Klappe 20% t
Re = 0,7 x 10^6
Re = 1,0 x 10^6
Re = 1,5 x 10^6
Re = 2,0 x 10^6
Re = 2,5 x 10^6
Re = 3,0 x 10^6
t
0,2 x t
β
Spalt dicht
α
u∞
Ca
Cm1/4
10^3 Cw
α°
β = 0°
+10° +5°
+15°
-10° -15° -20°
β = -20° -15° -10° -5° 0° +5°
-25°
INSTITUT FÜR AERODYNAMIK UND GASDYNAMIK
der Technischen Hochschule Stuttgart
Laminarwindkanal
Messg. v. 8.10.62
gezeichn.
gepr.
Profilmessung
Zeichnungs-Nr. 22/1

5.6 MARSDEN UAG-143/20 - 14.3 % FLAPPED SECTION



X	Y_u	Y_l
0.00000	0.00000	0.00000
0.00293	0.01051	-0.00334
0.01169	0.02290	-0.00740
0.02617	0.03605	-0.01176
0.04621	0.04965	-0.01362
0.07157	0.06351	-0.01476
0.10195	0.07714	-0.01516
0.13700	0.08995	-0.01505
0.17631	0.10162	-0.01445
0.21941	0.11177	-0.01350
0.26579	0.12014	-0.01268
0.31493	0.12663	-0.01182
0.36623	0.13108	-0.01092
0.41911	0.13330	-0.00999
0.47293	0.13319	-0.00904
0.52707	0.13061	-0.00809
0.58089	0.12539	-0.00714
0.63376	0.11726	-0.00621
0.68507	0.10626	-0.00531
0.73420	0.09258	-0.00444
0.78059	0.07581	-0.00363
0.82369	0.05853	-0.00287
0.86300	0.04470	-0.00218
0.89805	0.03350	-0.00156
0.92843	0.02378	-0.00103
0.95379	0.01582	-0.00058
0.97383	0.00960	-0.00023
0.98831	0.00480	0.00003
0.99707	0.00155	0.00018
1.00000	0.00000	0.00000

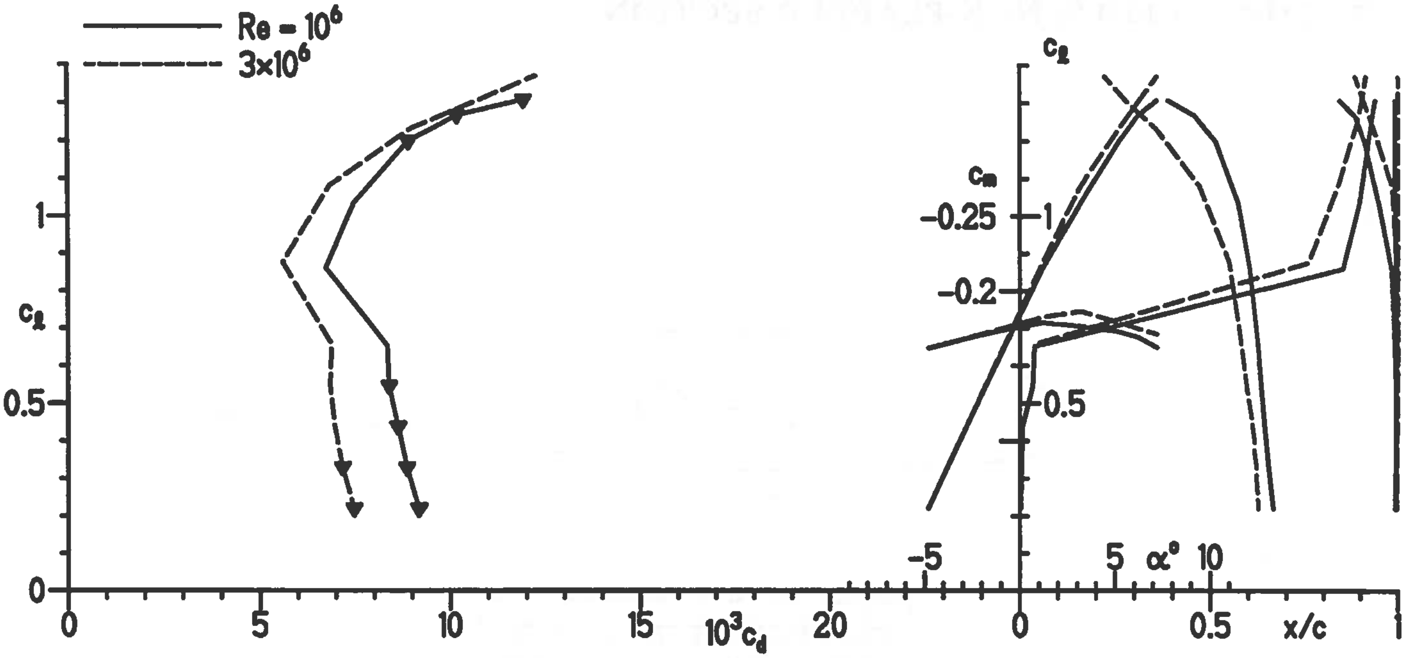
Table 5: Marsden UAG 88-143/20



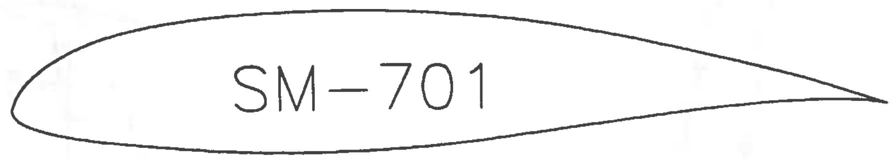
UAG 88 143/20
C_L
C_D
2.0
1.5
1.0
0.5
0.0
0.000
0.005
0.010
0.015
0.020
RN = 1.0*10^6
flap = 0°
flap = +10°
flap = −10°
flap = −5°

EPPLER 23.3.92

UAG 88-143 14.33%

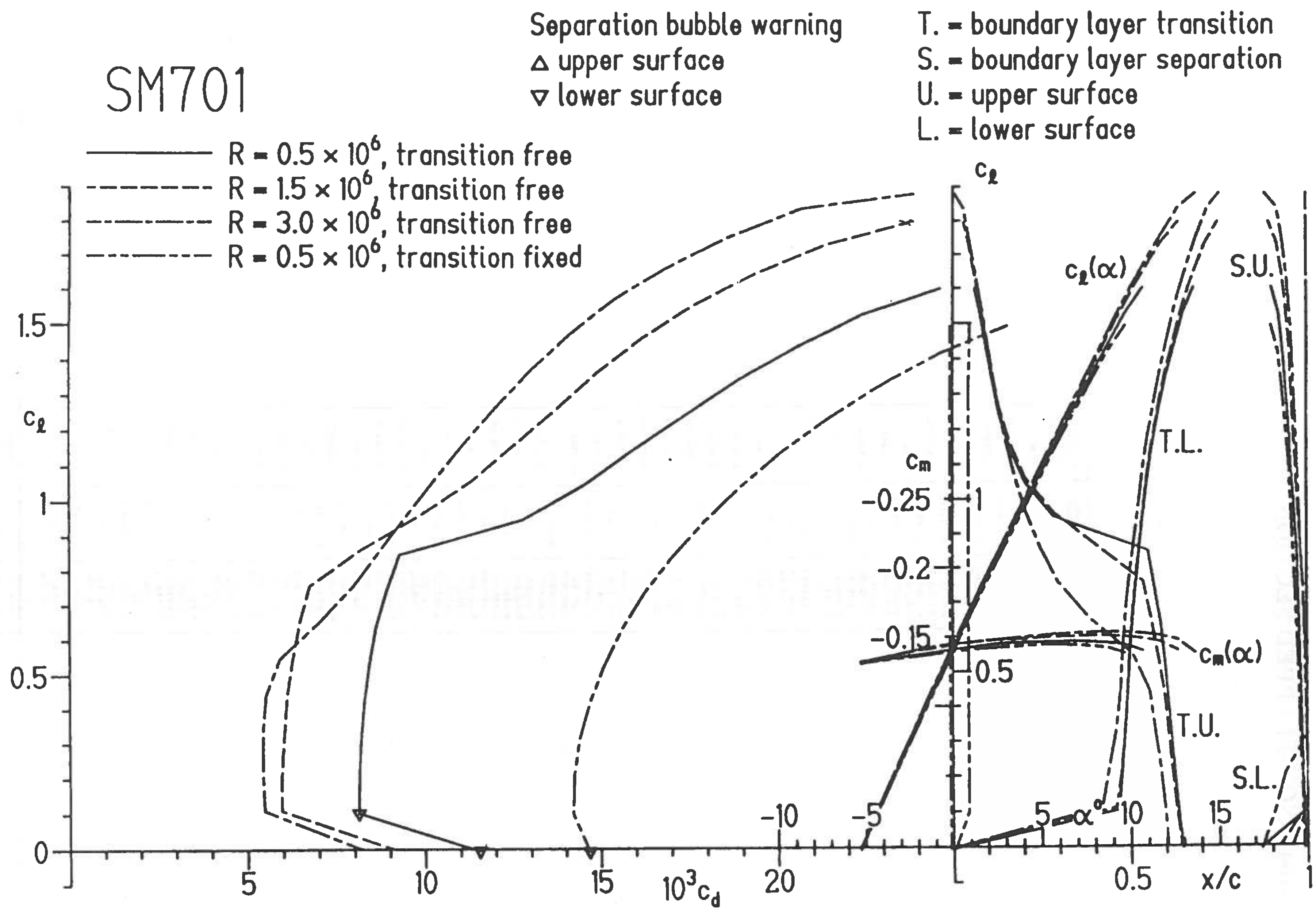


5.7 SM-701 - 16.0 % NON-FLAPPED SECTION



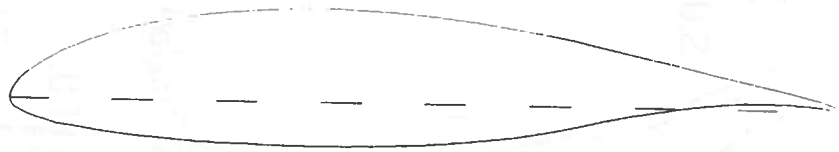
X_u	Y_u	X_l	Y_l
0.00168	0.00771	0.00016	-0.00212
0.00736	0.01910	0.00435	-0.00981
0.01701	0.03121	0.01501	-0.01632
0.03055	0.04344	0.03127	-0.02244
0.04794	0.05534	0.05277	-0.02800
0.06915	0.06648	0.07923	-0.03294
0.09417	0.07658	0.11036	-0.03726
0.12295	0.08544	0.14575	-0.04101
0.15541	0.09296	0.18488	-0.04418
0.19133	0.09914	0.22722	-0.04670
0.23041	0.10397	0.27222	-0.04849
0.27229	0.10746	0.31929	-0.04943
0.31654	0.10964	0.36784	-0.04938
0.36268	0.11055	0.41726	-0.04803
0.41019	0.11018	0.46727	-0.04488
0.45853	0.10853	0.51811	-0.03983
0.50714	0.10557	0.56979	-0.03340
0.55548	0.10120	0.62191	-0.02623
0.60323	0.09517	0.67386	-0.01887
0.65041	0.08760	0.72497	-0.01182
0.69676	0.07903	0.77446	-0.00553
0.74171	0.06990	0.82144	-0.00041
0.78466	0.06055	0.86497	0.00324
0.82498	0.05125	0.90406	0.00526
0.86207	0.04221	0.93768	0.00567
0.89529	0.03348	0.96489	0.00463
0.92431	0.02493	0.98462	0.00262
0.94922	0.01669	0.99524	0.00073
0.96999	0.00946	1.00000	0.00000
0.98605	0.00405		
0.99640	0.00095		
1.00000			

Table 6: SM701 16.0 % non-flapped section



SM701
R = 0.5 × 10^6, transition free
R = 1.5 × 10^6, transition free
R = 3.0 × 10^6, transition free
R = 0.5 × 10^6, transition fixed
Separation bubble warning
△ upper surface
▽ lower surface
T. = boundary layer transition
S. = boundary layer separation
U. = upper surface
L. = lower surface
c_l
1.5
1
0.5
0
5
10
15
10^3 c_d
20
-10
-5
5
α°
10
15
c_m
-0.25
-0.2
-0.15
0.5
x/c
1
c_l(α)
c_m(α)
T.L.
T.U.
S.U.
S.L.

6.9 DU-184 - NON-FLAPPED SECTION



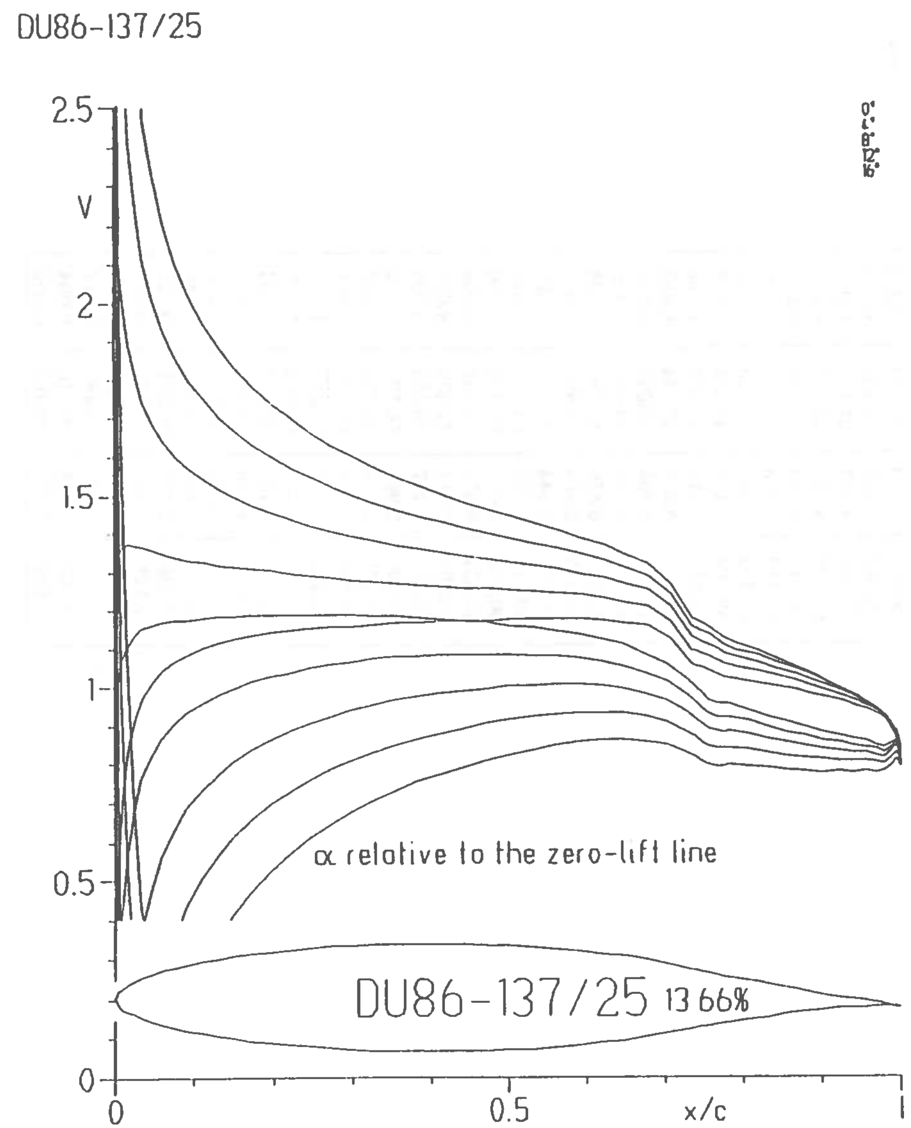
DU 80-141

X_l	Y_u	Y_l
0.0000	0.0000	0.0000
0.000036		-0.000976
0.000663	0.004492	
0.001492		-0.005725
0.003029	0.010469	
0.005356		-0.009942
0.006994	0.016799	
0.011587		-0.013852
0.012600	0.023304	
0.019829	0.030009	
0.019910		-0.017697
0.028613	0.036848	
0.030211		-0.021423
0.038891	0.043688	
0.042429		-0.024980
0.050618	0.050458	
0.056493		-0.028358
0.063749	0.057091	
0.072331		-0.031543
0.078250	0.063528	
0.089849		-0.034534
0.094083	0.069720	
0.108952		-0.037316
0.111193	0.075608	
0.129524	0.081149	
0.129558		-0.039877
0.149024	0.086315	
0.151568		-0.042257
0.169627	0.091070	
0.174890		-0.044411
0.191264	0.095372	
0.199421		-0.046297
0.213871	0.099189	
0.225037		-0.047960
0.237384	0.102479	
0.251639		-0.049369
0.261734	0.105227	
0.279129		-0.050496
0.286843	0.107425	
0.307347		-0.051335
0.312630	0.109053	
0.336179		-0.051877
0.339019	0.110085	
0.365540		-0.052087
0.365927	0.110523	
0.393260	0.110351	
0.395277		-0.051951
0.420947	0.109560	
0.425246		-0.051460
0.448917	0.108169	
0.455339		-0.050566
0.477089	0.106183	
0.485420		-0.049252
0.505385	0.103598	
0.515357		-0.047445
0.533733	0.100455	
0.545025		-0.045017
0.562054	0.096779	
0.574273		-0.041933
0.590282	0.092581	
0.602903		-0.038256
0.618380	0.087881	
0.630802		-0.033907
0.646343	0.082720	
0.658209		-0.028803
0.674184	0.077191	
0.685693		-0.022744
0.701863	0.071245	
0.713656		-0.016575
0.729271	0.065274	
0.742090		-0.010962
0.756239	0.059405	
0.770814		-0.005818
0.782580	0.053626	
0.799588		-0.001270
0.808118	0.048015	
0.828020		0.002420
0.832651	0.042636	
0.855595		0.005068
0.856019	0.037528	
0.878061	0.032714	
0.881762		0.006610
0.898627	0.028228	
0.905981		0.007094
0.917548	0.024078	
0.927798		0.006736
0.934667	0.020247	
0.946929		0.005797
0.949875	0.016725	
0.963078	0.013505	
0.963224		0.004549
0.974190	0.010524	
0.976575		0.003210
0.983179	0.007654	
0.986897		0.001921
0.990138	0.004909	
0.994189		0.000876
0.995282	0.002467	
0.998530		0.000220
0.998785	0.000639	
1.000000	0.000000	0.000000

6.10 DU-86-137/25 - HORIZONTAL TAILPLANE SECTION

X_u	Y_u	X_l	Y_l
100.000	0.000	0.047	-0.301
99.871	0.014	0.294	-0.696
99.492	0.056	0.764	-1.091
98.880	0.124	1.435	-1.502
98.043	0.219	2.290	-1.925
96.988	0.341	3.318	-2.352
95.722	0.488	4.516	-2.770
94.254	0.661	5.882	-3.181
92.592	0.860	7.410	-3.583
90.745	1.084	9.093	-3.972
88.721	1.332	10.924	-4.348
86.531	1.605	12.894	-4.708
84.183	1.902	14.994	-5.048
81.686	2.223	17.216	-5.364
79.037	2.571	19.552	-5.655
76.229	2.984	21.994	-5.918
73.352	3.541	24.533	-6.151
70.546	4.177	27.157	-6.351
67.796	4.723	29.857	-6.517
65.012	5.168	32.625	-6.646
62.179	5.555	35.450	-6.736
59.305	5.881	38.323	-6.788
56.394	6.154	41.232	-6.799
53.454	6.379	44.169	-6.768
50.494	6.558	47.124	-6.695
47.526	6.695	50.084	-6.582
44.559	6.790	53.040	-6.426
41.606	6.876	55.980	-6.228
38.678	6.864	58.894	-5.984
35.786	6.844	61.773	-5.691
32.941	6.788	64.612	-5.347
30.155	6.697	67.410	-4.950
27.439	6.571	70.167	-4.506
24.803	6.411	72.880	-4.019
22.256	6.217	75.554	-3.500
19.809	5.992	78.191	-2.970
17.471	5.735	80.775	-2.457
15.249	5.448	83.286	-1.981
13.152	5.132	85.696	-1.553
11.186	4.791	87.982	-1.179
9.359	4.425	90.121	-0.862
7.677	4.039	92.092	-0.604
6.146	3.636	93.875	-0.398
4.774	3.218	95.455	-0.242
3.565	2.788	96.821	-0.128
2.524	2.349	97.963	-0.058
1.656	1.904	98.855	-0.030
0.964	1.457	99.488	-0.017
0.453	1.015	99.870	-0.004
0.138	0.578	100.000	0.0000

Table 3: Delft DU86-137/25 13.7% horizontal tailplane section


DU86-137/25
2.5
V
2
1.5
1
0.5
0
α relative to the zero-lift line
DU86-137/25 13.66%
0
0.5
x/c
1

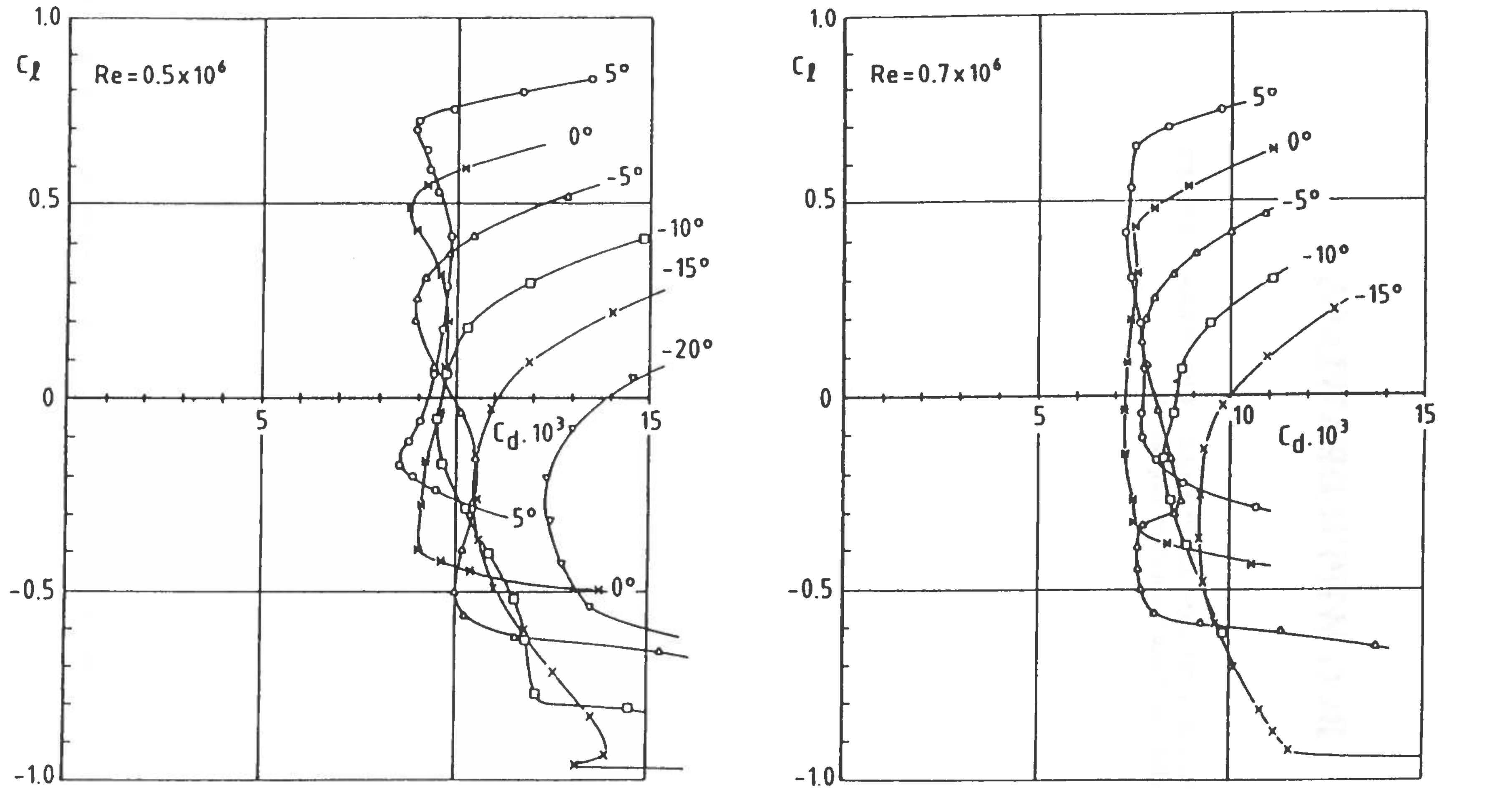
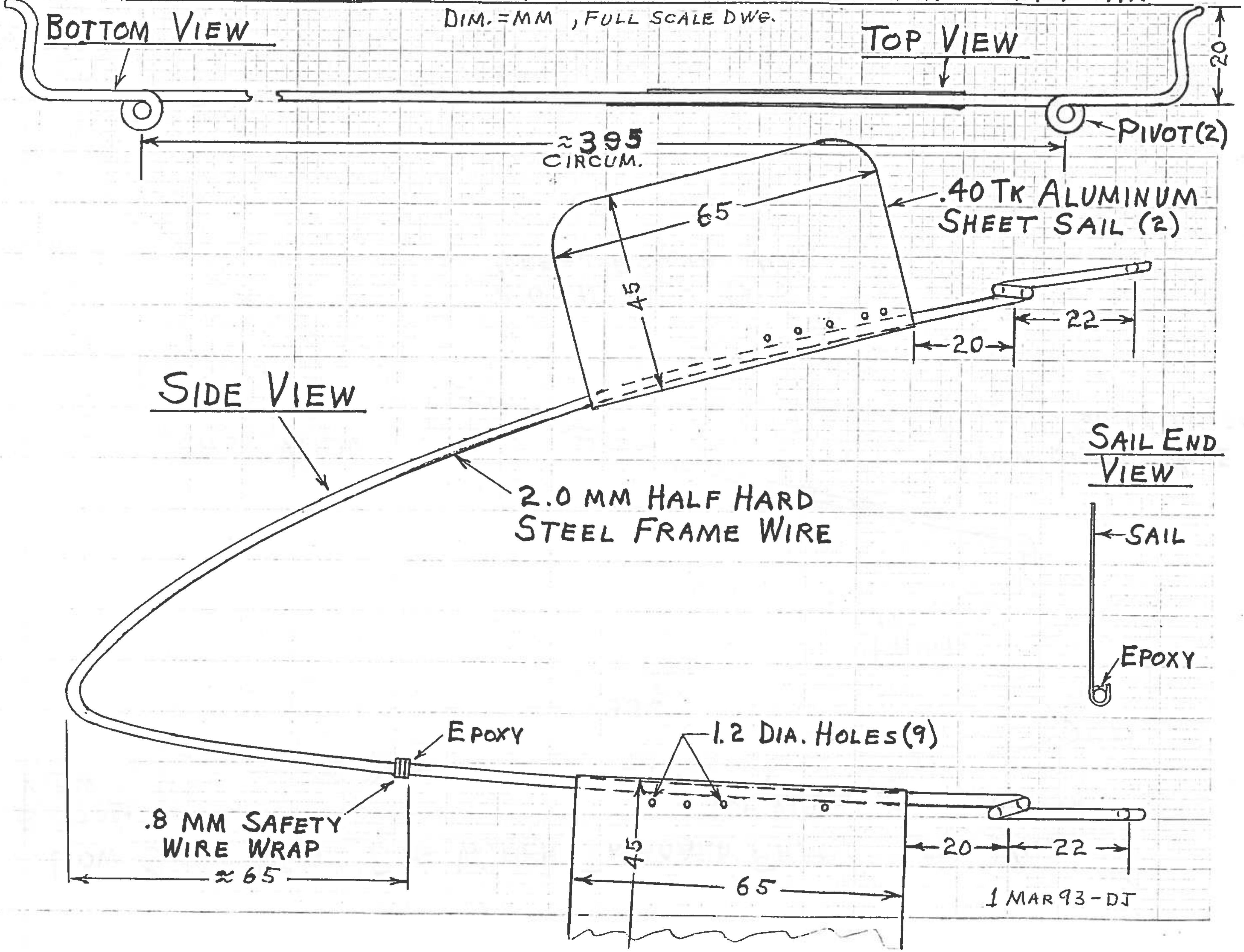


Fig. 7. Continued

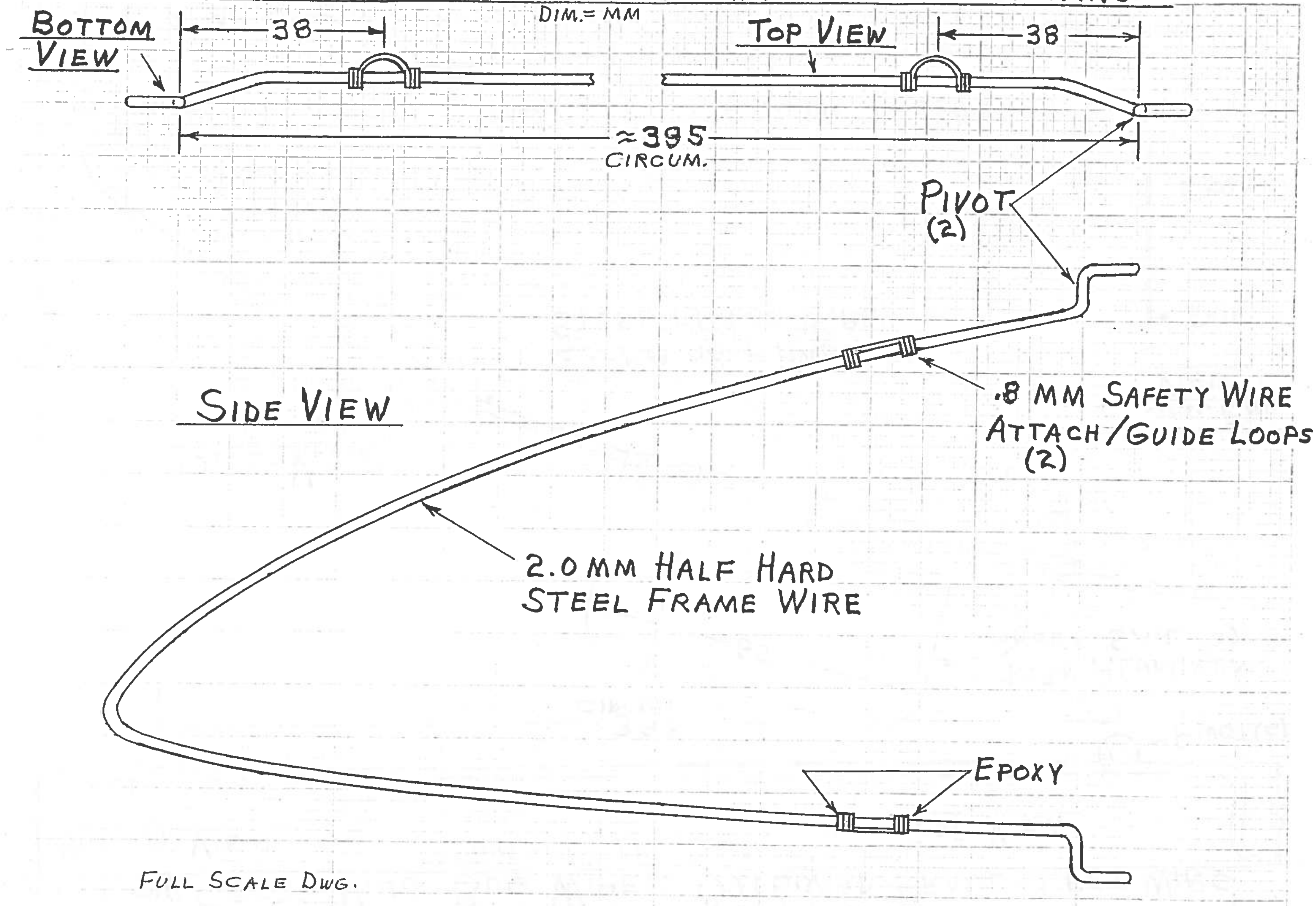
BUG WIPER DRAWINGS

The following three pages contain sketches of a type of low-cost bug wiper developed by Richard Johnson for sailplane use.

Low Cost Wing Bug Wiper Outboard Frame - Left Wing



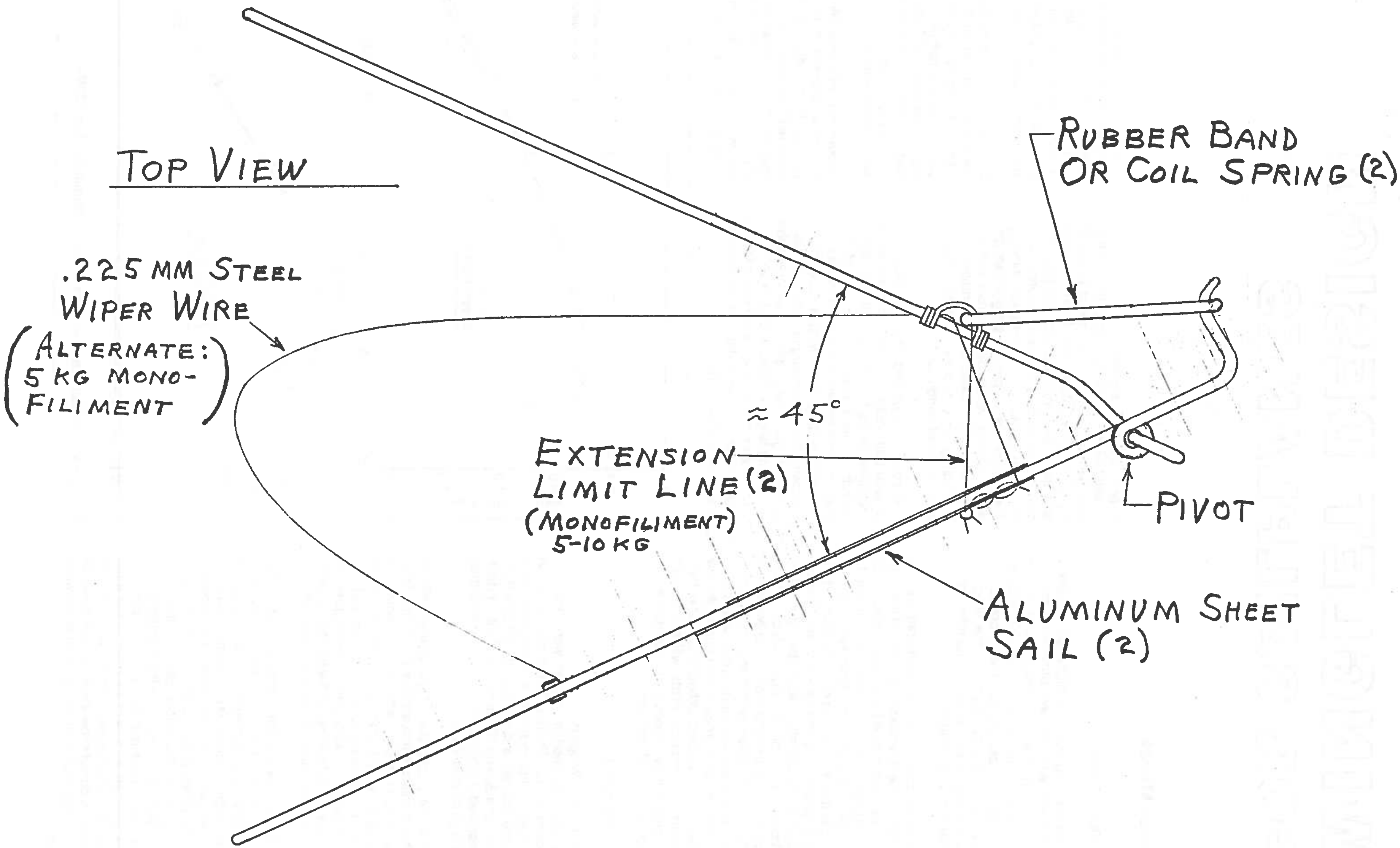
Low Cost Wing Bug Wiper Inboard Frame - Lfft Wing



1 Mar 93-DJ

Assembled Low Cost Wing Bug Wiper - Left Wing

Full Scale Dwg.



1 Mar 1993 - DJ

WINGLET DESIGN FOR SAILPLANES

Peter Masak

INTRODUCTION

In the ongoing quest for higher performance sailplanes, winglets have provided a means for improving the performance with only a modest price per L/D point gain. Winglets act to reduce induced drag and act to control the crossflow in the tip region of the wings in such a way as to improve the handling characteristics at the same time.

By introducing a vertical cambered surface at the tip, the downwash field behind the wing is spread horizontally by several inches. Since the induced drag is inversely proportional to the effective width of this downwash field, the winglet therefore acts to reduce induced drag by displacing the vortices outward. Presumably the greatest effect would be obtained by introducing a high lift large surface winglet which would displace more air outward and alter the circulation pattern in a more significant way. However the design of winglets involves the compromise of maximizing the low speed improvement without sacrificing high speed performance. Pilots will not fly with winglets if they perceive any deterioration of high speed performance.

BACKGROUND

First Use of Winglets
Winglets for modern aircraft were first proposed by Dr. Richard Whitcomb, at NASA Langley in the mid-1970's. At that time, wind tunnel models and subsequent full size flight tests on a Boeing 707 commercial jetliner demonstrated a significant reduction in total drag at high lift coefficients.

After the publication of the design philosophy, numerous researchers in industry tackled winglet design with varying degrees of success. Most tried to use potential flow methods for predicting tip inflow angles and surface pressure distributions, however given the nature of the flow field at the tip, this has lead many investigators to the wrong conclusions.

Potential flow analysis seems to steer the designer in the direction of excessively large winglets, while experimental data suggests that large winglets pay a greater-than-predicted penalty in high speed performance. Since potential flow methods cannot accurately predict the vortex roll-up at the tip, or the influence of secondary flows on the boundary layer, these methods have not provided the complete picture of the effect of the winglets on performance. Also the potential flow methods do not show the significant influence of the fore to aft positioning effect of the winglets.

Experience with Sailplanes
In sailplane racing circles, winglets were tried and then dropped by a number of University Flying Groups (Darmstadt, Braunschweig), and the French manufacturer Centrair. The overriding concern repeatedly expressed by racing pilots was that the winglets, although they were known to provide a significant gain at low speed, would detract from performance at the high speed cruise condition, with a resulting net loss or perhaps no achieved gain in overall performance.

This concern is justified since winglets act to reduce both induced drag and drag due to crossflow at the tip; however, at high speed neither of these effects are large and thus there is some speed at which the overall surface friction drag of the winglet exceeds the induced/interference drag reduction provided by the winglet. The graphs below shows this effect with large winglets added to an ASW-19 at Braunschweig. Clearly the key is to provide a minimum drag surface which does not stall at circling speeds.

Prompted by interest from Dr. David Marsden at the University of Alberta, and my own successful experience a decade ago with a home-built HP-18, the challenge was struck to design an efficient pair of winglets for a Nimbus III for the World championships in 1989 at Wiener Neustadt, Austria.

Marsden had proposed using an unusual double element winglet on the Nimbus III *(emulating the primary wing feathers of a soaring bird)* which was inspired by a successful version on Marsden's DG-200. His experiments had showed that he was obtaining a significant improvement in lift capability of a tip section fitted with winglets.

Experiments with Dual Winglets
The initial promise of dual winglets on the Nimbus III tips did not prove out in either flight tests or wind tunnel tests. Although a gain in lift was measured, the interference drag of the two lifting surfaces caused the airflow across the rear winglet to be separated at even modest lift coefficients. This re-

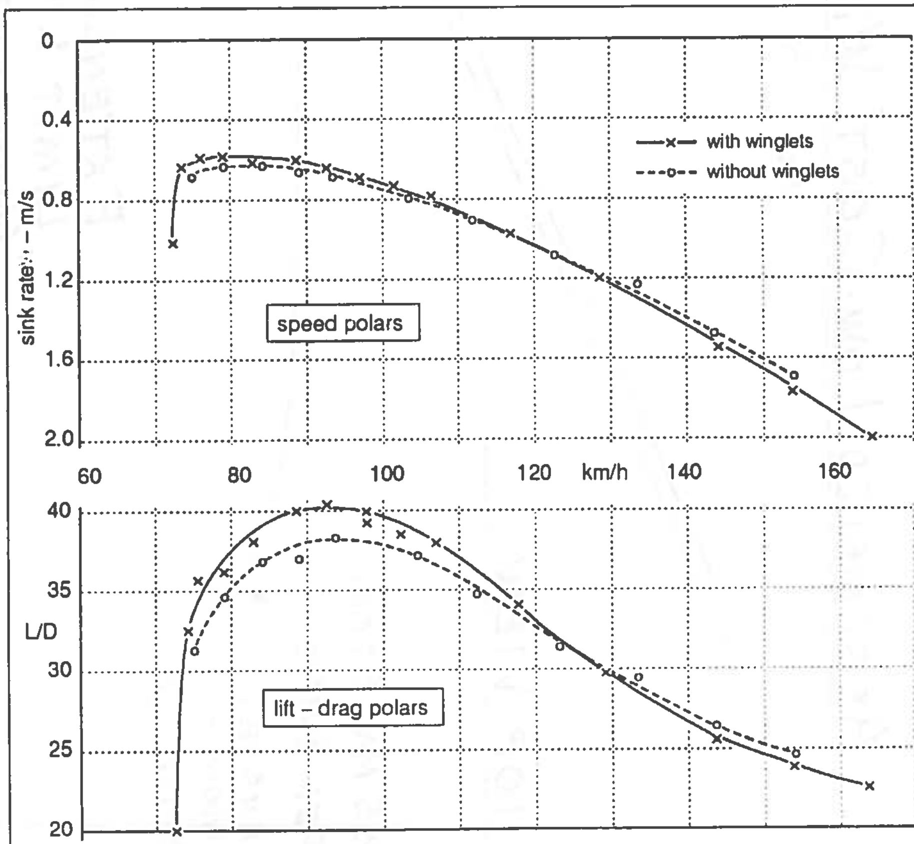


Figure 2 — Influence of winglets on the performance of an ASW-19

sulted in the winglet not being effective at either high or low flight speeds. At speeds below 55 knots, the rear winglet would experience massive separation (seen with tufts); and at speeds higher than that, the winglet friction drag due to the highly cambered airfoils was so high as to cause an overall loss.

Second Iteration
The narrow tip chord of the Nimbus III (9 in) forced an abnormally low chord for the dual winglets (3–4 in). The resulting low Reynold's number of the winglet elements probably contributed to the separation problem and high drag. Thus it was evident that this design could be improved by going back to the conventional single element winglet. *(An airfoil's Reynold's number is related to its size — all else being equal, a small airfoil does not "work" as well as a large one. The R_e of a typical sailplane wing is 1,000,000. ed.)*

DESIGN OPTIMIZATION

Apart from the selection of a winglet airfoil, there were five key parameters that had to be chosen to optimize the design:

- Cant angle
- Twist distribution
- Sweepback
- Taper ratio
- Ratio of winglet root chord to sailplane tip chord

Cant Angle
The selection of cant angle evolved from an unusual consideration specific to sailplanes: the narrow and highly flexible wings provide for a wingtip angle in flight which can approach 30 degrees on some sailplanes when flying with water ballast. A more common angle for modern 15 metre ships is 7–12 degrees.

On winglets that are nominally set to a cant angle of 0 degrees (at right angles to the wing), as the wing deflects, the winglet generates a sideload in flight which has a component oriented downward. This is a self defeating situation, since the winglet is generating additional drag by contributing to the weight of the aircraft. Thus a more reasonable approach is to set the winglets at least at a cant angle on the ground of 0 degrees plus the in-flight local tip deflection angle.

Sweepback
The selection of the sweepback angle was based on experimental observations. It was first believed that the sweepback angle for the winglet should be equal to that for the main wing (0 degrees), however experience proves otherwise. If a vertical winglet with no sweepback is built, it will be observed that the root of the winglet will stall first and that the tip will remain flying.

The optimum situation from an aerodynamic standpoint is to have the aerodynamic loading such that the entire winglet surface stalls uniformly. This can be achieved by sweeping back the winglet, which will increase the loading on the tip. Because of the rapid variation in angle of attack of the winglet as a function of height, a large degree of sweepback is required to load the tip correctly. For our winglets, a 30 degree leading edge sweep angle was used to achieve this effect.

Ratio of winglet root chord to sailplane tip chord
It would seem that the winglet might ideally be designed as an extension of the wing, and thus the optimum winglet would be a smooth transition of the wing from horizontal to vertical. Experiments suggest otherwise.

If the root chord of the winglet is equal to the tip chord of the wing, then the inflow angle at the tip will be less than when the winglet is a smaller fraction of the tip chord. The result will be that at high speed, the inflow angle may not be sufficient so as to prevent separation of the airflow from the outer (lower) surface of the winglet. Since other considerations require that a toe-out angle be set (about –3 degrees), it is desirable to allow some vortex induced flow to wrap around the wingtip and provide a positive angle of attack for the winglet at all flight speeds.

For the various winglets fabricated, the following ratios of root chord of the winglet to tip chord of the wing were used:

- DG–600 0.60
- Ventus 0.57
- ASW–20 0.50
- Discus 0.70
- Nimbus III 0.95

The choice of the root chord of the winglet is also constrained by the nominal tip chord of the wing, and by considering Reynold's number effects. Too small a winglet chord can result in extensive laminar separation and high drag. For the Nimbus III and Discus winglets, the small nominal tip chords force the winglet geometry to be smaller than would be desirable from a Reynold's number consideration.

Twist distribution
The twist distribution on a winglet is normally selected so as to provide a uniform load distribution across the winglet span. Since the inflow angle is higher at the base, the winglet is twisted to higher angles of attack toward the tip. This is opposite to the general design methodology for wings, which normally have washout (either geometric or aerodynamic) so as to decrease the angle of attack towards the tips.

The determination of optimum twist for our winglets was made by iterating experimentally. When flight tested, the first set of winglets fabricated stalled at the root first with a progressive stall developing upwards towards the winglet tip. By twisting the winglet to increase the angle of attack at the tip, the entire surface of the winglet could be made to stall simultaneously. Two degrees of twist from root to tip proved to be optimum.

The second benefit of positive twist on the winglet is that the high speed performance is enhanced — there is less likelihood of developing separation on the outer surface of the winglet at low inflow angles (high speed = low coefficient of lift, C_l).

Taper ratio
The effect of taper ratio on inflow angles and the resulting optimum twist distribution was analysed theoretically by K.H. Horstmann in his PhD thesis. It was shown that as taper ratio increases, the optimum twist distribution for the winglet varies more linearly from root to tip. From a construction standpoint it is also easier and more accurate to build a winglet with a linear change in twist angle along the winglet span. This favours a winglet with a larger tip chord. We also want to try to maximize the tip chord so as to maximize the Reynold's number. Accordingly, a ratio of tip to root chord of 0.6 was selected.

Toe-out
The determination of toe-out was based on the simple consideration that we were trying to maximize the speed at which no further benefit is gained from the winglet, and thus select an angle of attack (α) setting for the winglet that will minimize the high speed drag.

Considering the C_l-vs-α prediction for the PSU–90–125 winglet airfoil, an angle of attack of –3 degrees corresponds to a C_l of 0. Given the fact that even at high speed there is a small inflow component at the tip, the winglet will actually be generating a slightly positive lift, even with the –3 degree root toe-out. Calculations show that when the wing is operating at a nominal lift coefficient of 1.0 (which corresponds to the circling lift coefficient), the lift coefficient of the winglet is 0.6 at the root and reduces to zero at the tip.

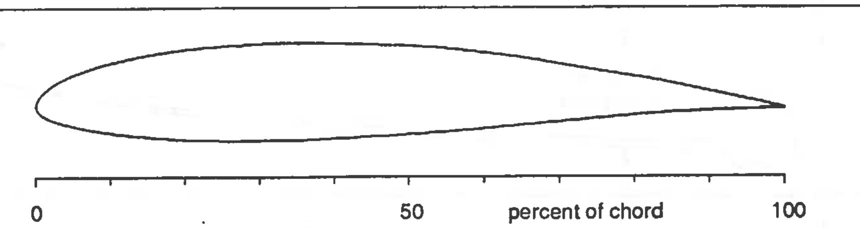
WINGLET AIRFOIL

The winglet airfoil was designed with the following criteria in mind:

- to minimize drag at low C_l conditions
- to design the winglet airfoil to be tolerant of low R_e
- to maximize tolerance to negative α

These design requirements are different than for a conventional sailplane airfoil. The resulting custom airfoil designed by Dr. Maughmer and Mr. Selig of Pennsylvania State University is shown in the figure below. Dr. Maughmer described the airfoil design philosophy as follows:

"The airfoil has the traditional undercamber removed from the lower surface trailing edge area, which minimizes the tendency to form detrimental laminar separation bubbles at low or negative angles of attack. At the price of a little C_{lmax}, which isn't important for a winglet anyway, the drag is lower than other sailplane airfoils everywhere up to C_l =0.85, as well as



PSU–90–125 winglet airfoil

at negative C_l's, so that sideslips and horizontal gusts can be tolerated. The corners of the laminar bucket have been rounded to avoid unstable yawing moments that would be generated otherwise if the sailplane yawed to angles exceeding those corresponding to the sharp corners of the traditional Wortmann sailplane airfoils. Finally, the airfoil was designed to avoid laminar separation bubbles down to R_e = 350,000."

WING AERODYNAMICS

The change in the lift distribution of a wing with and without winglets is shown below. The boundary condition at the wingtip of the main wing no longer requires that the lift taper to zero at the tip. The assumed lift distribution for a wing with a winglet is assumed to terminate at an imaginary point equal to unfolding the vertical winglet in the horizontal plane. As a result the outer portion of the wing carries a higher load than it does without the winglet. Recent calculations on sailplanes with double trapezoidal planforms such as the ASW-20 or LS-6 suggest that this outer tip loading is more efficient from the standpoint of induced drag.

Secondly, the additional lift capability of the main wing means that the C_{lmax} of the overall wing is increased and the sailplane's circling performance will be enhanced.

Structural Loading

One of the key advantages of winglets is that they provide a performance increase while only fractionally increasing the root bending moment on the spar compared to a span extension. Whereas the moment arm of a span extension is one-half the semi-span of the wing (about 7.5 metres), the moment arm of a winglet is only equal to approximately one-half the vertical span (0.3 m) plus the deflected wing elevation at the tip. For sailplanes which are certified with tip extensions, one can be assured that the winglet will not overload the wing and all standard operating limitations will apply (Ventus, ASW-20, DG-600).

FINAL DESIGN

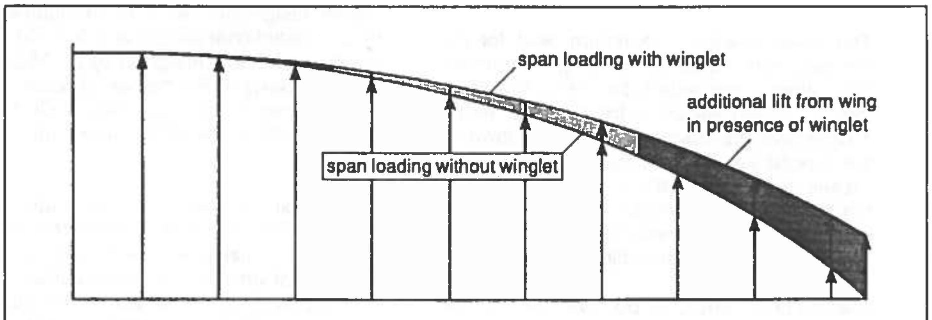
The final choice of design parameters is reflected in the design of the Ventus and ASW-20 winglets, which have been highly successful in competition. The ASW-20 winglet went through two iterations and the Ventus, three, before it was concluded that the design had reached a high level of refinement.

FLIGHT TEST RESULTS

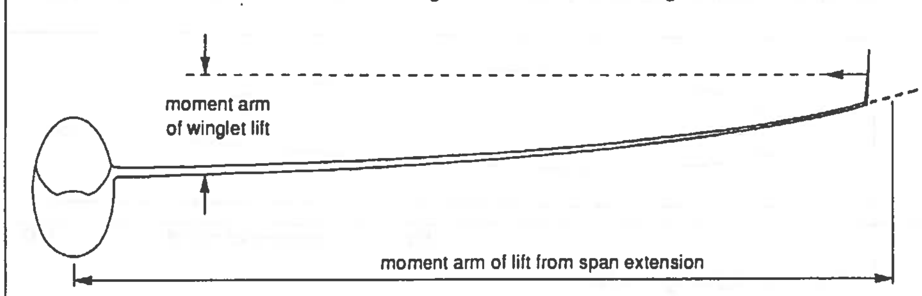
Competition Results

The response of pilots flying with winglets in competition has been very positive overall. Certainly one of the measures of the success of the design is the fact that pilots after a period of evaluation have chosen to fly with the winglets. At the 1991 world contest in Uvalde, Texas, ten pilots chose to fly with our winglets – 8 Ventus, 1 ASW-20B, and 1 Nimbus III. At the end of the contest, a Ventus flying with our winglets had won four of twelve contest days and on the fastest day of the contest, the top five places in the 15 metre class went to sailplanes flying with our winglets. Additionally the trophy for the highest speed achieved overall went to Jan Anderson of Denmark, flying a Ventus with our winglets (his speed also exceeded the highest achieved in the Open Class). Two weeks prior, at the 15 metre nationals in Hobbs, New Mexico, Rheinhard Schramme from West Germany established an unofficial record of sorts by flying his Ventus-C around a closed course of greater than 500 km with an average speed of 171 km/h (he would have won were it not for a photo penalty).

Bruno Gantenbrink and Hermann Hajek of West Germany chose to retrofit winglets to their Ventus-C's and were delighted with the handling and performance qualities that they observed. Mr. Hajek noted as a particular advantage the improvement in his ability to maintain constant bank angle and speed with a full load of water. With winglets the effective dihedral is increased and the sailplane can be banked steeper while retaining control.



Lift distribution on a wing with and without winglet



The dolphining performance is naturally improved with the winglets since they act to reduce induced drag while pulling positive 'g's, and several pilots have perceived their sailplanes to have improved glide performance even at high cruising speeds in strong weather.

Flight Test Data

These positive results are confirmed by flight tests based on three high tows with each sailplane type which show the following performance gains as measured by the two-glider comparison technique.

ASW-20 flight test data:
(pilots –Striedieck, Seymour)

speed	duration	Δ with winglets	Δ ft/min
50 mi/h	5 min	+ 30 ft	6
65 mi/h	5 min	+ 7 ft	1.5
80 mi/h	2 min	+ 10 ft	5
100 mi/h	2 min	0	0

Ventus flight test data:
(pilots –Mockler, Masak)

speed (knots)	flap	Δ with winglets
40 dry, 53 wet	+2	9.1 ft/min
50 dry, 66 wet	0	9.0 ft/min
60 dry, 79 wet	0	9.8 ft/min
84 dry, 110 wet	–2	3.3 ft/min

Maximum performance gains
with Masak winglets

sailplane	winglet airfoil	L/D gain
ASW-20	NASA Van Dam	2.1
Discus	PSU-90-125	2.5
Ventus	PSU-90-125	3.5

CONCLUSIONS

The overall performance gains measured in free flight on sailplanes retrofitted with winglets are impressive and are supported by positive contest results. Handling qualities are improved in all cases, including improvement in roll rate and roll authority at high lift conditions.

The performance measurements have shown a higher gain in performance than would otherwise be predicted by conventional theory. It is believed that major benefits are derived from inhibiting the secondary flow that contaminates the boundary layer near the tip region. Prediction of this phenomenon requires computational power out of my grasp, and the present designs have been developed via experimentation and in-flight testing.

By August 1991, there were over forty-five sailplanes in the world flying with winglets designed and fabricated by the author. No negative reports or dangerous incidents (ie. flutter) of any kind have been reported. As a result of the positive service experience, DoT have recently issued a supplementary type certificate for flight with winglets on the Ventus model, using JAR-22 as a basis for compliance. •

A bibliography is on page xx

DESIGN OF A NEW LOWER DRAG SAILPLANE HORIZONTAL STABILIZER

by Peter Masak and Ron Tabery, 8/13/92

ABSTRACT:

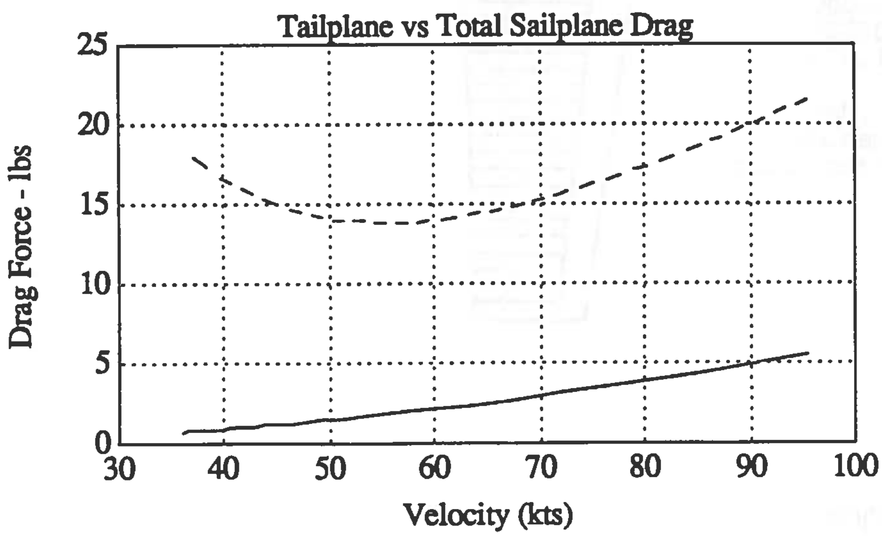
While often neglected as a potential candidate for drag reduction, the horizontal tailplane of a sailplane can still be improved over state-of-the-art designs. The horizontal tailplane does represent a significant amount of the total sailplane drag at higher cruising speeds.

Conversely, the low speed characteristics are also important, since they are the primary factor in sizing the tail area, and secondly, play an important role in determining the center of gravity range of the aircraft.

A new improved tailplane design has been made, which sports a double-tapered planform with heavily swept tips, and the latest in low-drag low-Reynold's number tailplane airfoils. The resulting drag of the tailplane is 12% lower drag at cruise conditions and 18% lower at thermalling conditions than the baseline ASW-20 tailplane.

INTRODUCTION

The drag of a well designed tailplane is mostly a factor at high cruising speeds. At 100 knots, the drag of a tailplane can represent as much as 25% of the total sailplane drag. This does not even consider the junction drag caused by the typically poorly faired elevator drive system. Figure 1 shows a drag buildup calculation for a typical sailplane with a Wortmann FX71-L-150 tailplane, assuming that the sailplane is perfectly balanced and no trim drag has been accounted for.



In this figure, the dotted line represents total aircraft drag. The solid line is the tailplane drag component. At 100 knots, the tailplane drag is 6 pounds, compared to a total of 23 pounds force for the entire aircraft including the tail.

NEW DEVELOPMENTS

Two new developments have encouraged a revisit of tailplane design. The design of a lower-drag profile optimized for tailplanes - the DU-86/137, and the use of a multiple tapered planform which have proved to be so successful on aircraft like the Discus.

As a baseline comparison, we have selected the popular ASW-20 tailplane as representative of a tailplane used on a typical state-of-the art high-performance sailplane. This sailplane, like most others developed in the last two decades, uses the popular Wortmann FX-71-L-150 symmetrical profile. The planform of the tailplane uses a simple straight taper. To analyse the planform effects, we have created an input file with the geometry shown in figure 1.

```
Reference  Values

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bref:          2.2000
Xref:           .0000
Yref:           .0000
Zref:           .0000
Nelem:              1
alpha:      14.00000
beta:         .00000
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qhat:         .00000
rhat:         .00000
Mach:         .00000
WakeLoc:       1.000
reflect:           1
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ForceFile: Forces.dat
ElementFile: Element.dat
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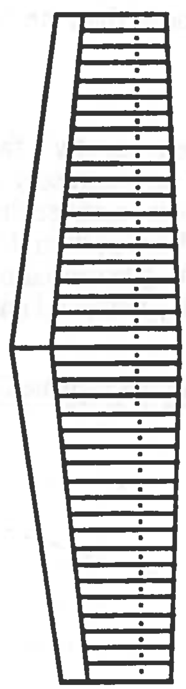
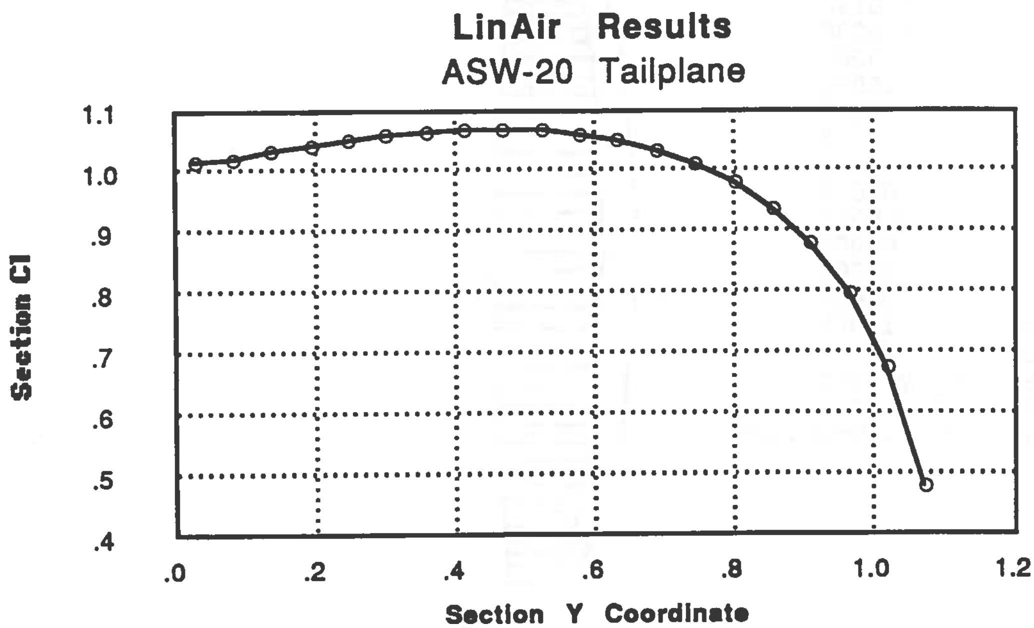


PLANFORM SELECTION

It is well known that lifting line theory predicts that a straight taper wing suffers from tip stalling problems since the tips operate at higher section lift coefficients than the root. The result is that the maximum lift coefficient of the wing, or tailplane in this case is limited by the section lift coefficient. The ideal wing will have the same section lift coefficient distributed along the span, which can only be achieved in an elliptical planform. Figure 1 shows the section lift coefficient vs. semispan

for the ASW-20 when operating at an angle of attack of 10 degrees. These numbers were computed using a vortex lattice technique (ref 1).



An improved geometry with a triple taper planform is shown below. The corresponding section lift distribution is also illustrated.

```
Reference  Values

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bref:          2.4000
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Yref:           .0000
Zref:           .0000
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beta:          .00000
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qhat:          .00000
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Mach:          .00000
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reflect:            1
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ForceFile: Forces.dat
ElementFile: Element.dat
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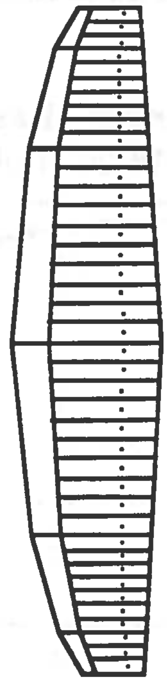
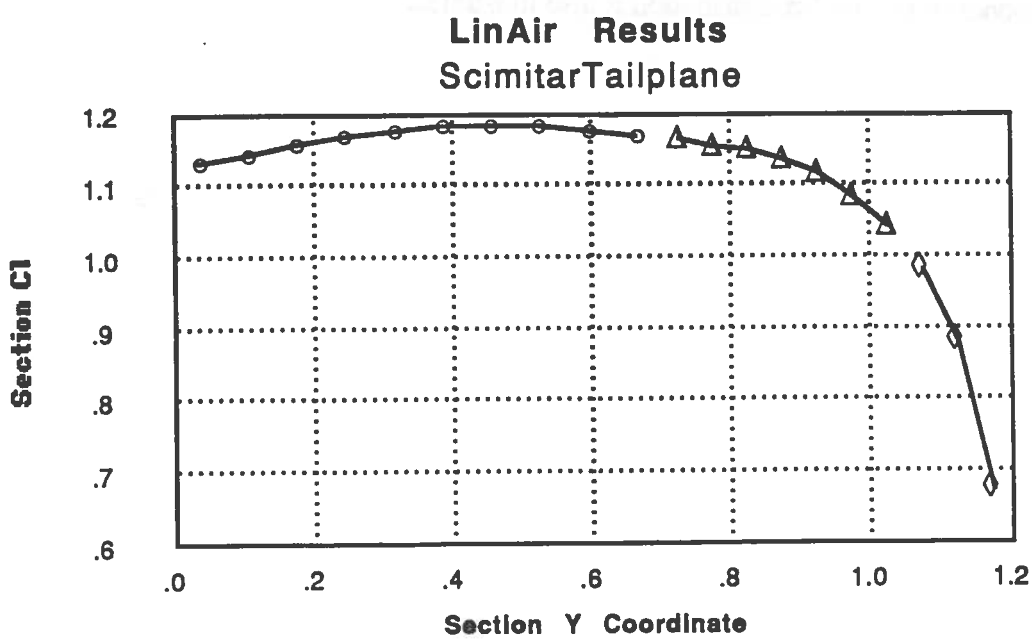
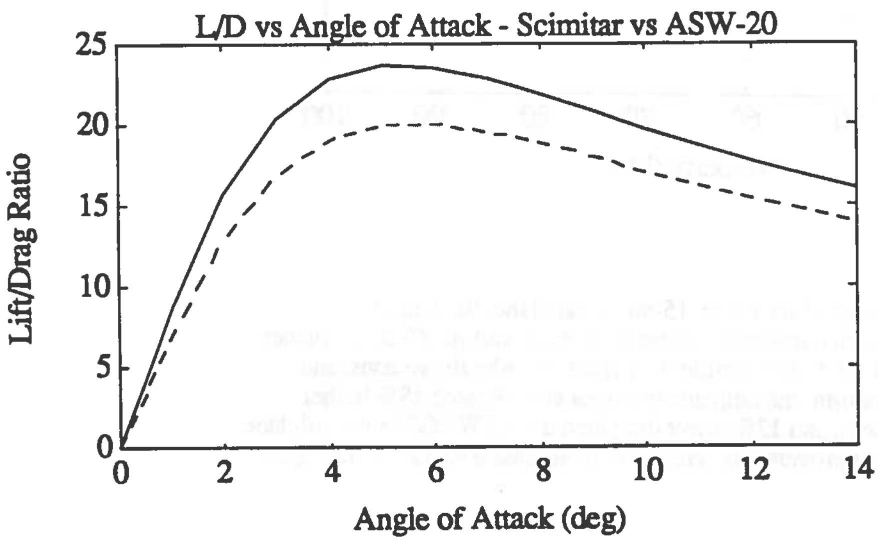


The following graph illustrates the computed section lift coefficients at an angle of attack of 15 degrees for the tail as a function of semispan coordinate:



The computed section lift coefficients show that with the triple-tapered tail planform, there is a small improvement in lift capability for the tailplane due to added lift being carried at the tip and the root.

The real improvement shows up when the lift/drag ratio is plotted. Here the maximum gain of 18% in L/D is demonstated for the new tail design vs. the old. These results include the effects of induced and friction drag.

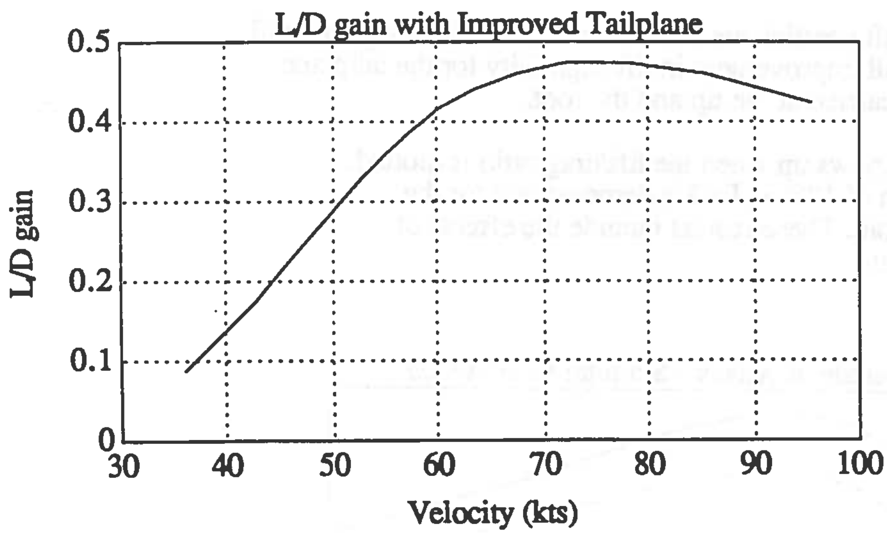


At climbing conditions, and especially in rough thermals with forward center of gravity locations, the tailplane may be called on to generate vertical loads on demand from the pilot. Although most pilots may think that they are flying with near neutral lift from the tail, the reality is that to keep the airplane flying, the elevator is constantly being worked. Thus the zero-lift low-Cl drag coefficient is much less relevant than the positive-or-negative Cl case.

PERFORMANCE PREDICTION:

Using the computed drag coefficients for the new tailplane, we can estimate what improvement is possible with the new geometry and improved profile. Although the tailplane drag has been reduced by significant amounts, the overall improvement is actually lower than might be expected since the improvement is only acting on the 25% of the total sailplane drag.

Assuming a sailplane weight of 700 lbs, and no trim drag, the simulation predicts an improvement of approximately 0.5 L.D points:



CONCLUSION:

A new tailplane has been designed for a new 15-meter sailplane, the Scimitar. The same tailplane may also be retrofitted to Discus, Ventus, and ASW-20 sailplanes. Based on the lower drag DU-86-137/25 profile developed by Luke Boermanns, and sporting a more modern planform, the tailplane provides an estimated 18% higher lift drag ratio at circling speeds, and 12% lower drag than the ASW-20/Ventus tailplane at cruise conditions. These improvements will result in at least 0.45 L/D points gain from 70 knots and higher .

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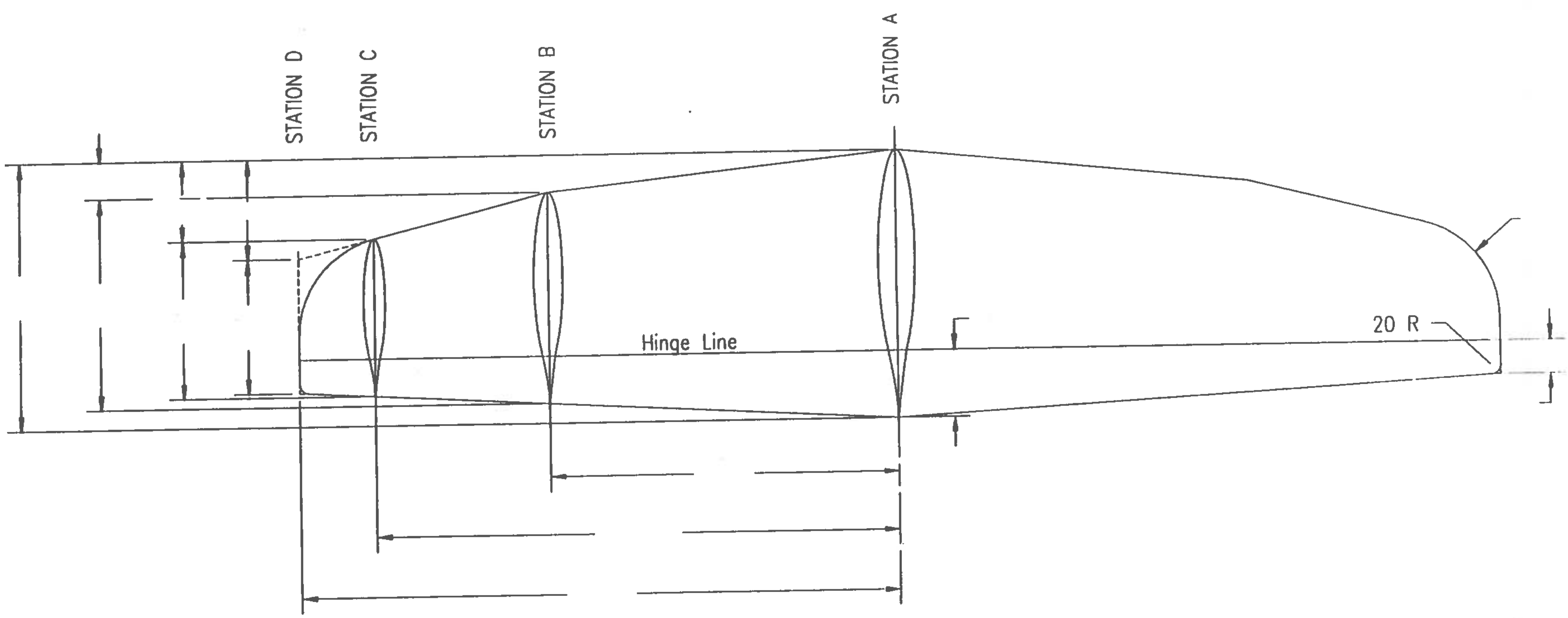

SCIMITAR TAILPLANE

AREA: 1.014 m^2

ASPECT RATIO: 5.68

PROFILE: DU86-137/25

REVISIONS			
LTR	ECO NO	DATE	BY
A	-	-	P C MASAK

DIMENSIONS IN MM UNLESS OTHERWISE NOTED

DO NOT COPY, DISPLAY, OR USE DRAWING WITHOUT AUTHORIZATION - DO NOT SCALE DRAWING -

STANDARDS - UNLESS OTHERWISE SPECIFIED

TOLERANCES DECIMALS .X = ± 0.05 XX = ± 0.005 XXX = ± 0.0005

ANGLES 0.1 deg

P C MASAK 9/13/92

P C MASAK 9/13/92

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PERFORMANCE ENHANCEMENT
Katy, Texas USA

TAILPLANE
SCIMITAR

DWG NO 92-029 REV A

SCALE NTS SHT 1 OF 1

Chapter 7

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